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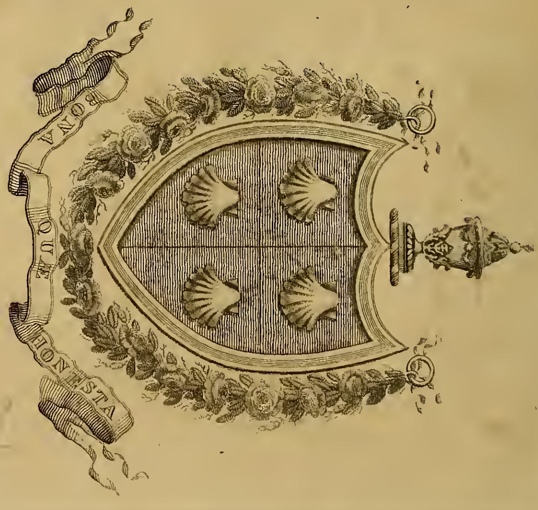

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For Doctor J. Jackson
with the best respects
of his friend & pupil
the Translator.

A SUMMARY OF PHYSIOLOGY,

BY

F. MAGENDIE,

Doctor of Medicine of the Faculty of Paris; Professor of Anatomy, Physiology and Semeiology; Member of the Société Philomatique, and the Société Médicale d'Emulation; Associate of the Medical Society of Stockholm, &c.

TRANSLATED FROM THE FRENCH,

BY JOHN REVERE, M. D. &c. &c.

SECOND EDITION.

Baltimore:

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John D. Toy, printer

1824.

7335
James Jackson M.D.
June 20, 1854

DISTRICT OF MARYLAND, TO WIT:

BE IT REMEMBERED. That on this first day of January, in the forty-eighth year of the independence of the United States of America Edward J Coale of the said District hath deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit:

"A Summary of Physiology By F Magendie, Doctor of Medicine of the Faculty of Paris: Professor of Anatomy, Physiology and Semeiology: Member of the Societe Philomatique, and the Societe Medicale d'Emulation: Associate of the Medicale Society of Stockholm, &c Translated from the French, by John Revere, M. D. &c. &c Second Edition."

In conformity with the Act of the Congress of the United States, entitled, "An Act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies, during the times therein mentioned;" and also to the Act, entitled, "An Act Supplementary to the Act, entitled, 'An Act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of soch copies, during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving, and etching, historical and other prints."

PHILIP MOORE,
Clerk of the District of Moryland

NOTICE.

It is little more than eighteen months since the first edition of this translation was published, and it is already out of print. Remotely as the translator feels himself connected with the merit of the work, he cannot allow the present opportunity to pass without making his acknowledgements for a success so rare with professional works. Owing to circumstances in which the public are but little interested, but over which the translator had no control, he was under the necessity of either abandoning altogether an enterprize on which he had expended much labour, which was nearly completed, and in which his feelings had become interested, or to hurry the first edition through the press, before it had received that patient and careful revision which such a work requires. For this reason many errors have crept into the first edition; but in the present, he has omitted no attention, nor spared any labour in endeavouring to make it deserving of the patronage which it has received.

In his ideas of what constitutes the excellence of a translation, he is sensible that he differs from many persons for whose judgment he entertains the highest respect. A nearly literal translation of the expressions of the original, is the mode generally adopted, and often most approved of. It is maintained that, unless this be done, we impute to the original thoughts and expressions which he never meant to utter, and deprive him of others which he intended to express. That, in fact, we can only approach the precise shade of thought which the author intended to convey by copying, as literally as possible, his particular modes of expression. It has been urged also, that this is especially necessary in scientific works, and that when it is omitted an injustice is done both to the public and the author.

These remarks are not without force, and, in some respects, must be considered just. But on the other hand, it may be replied, the modes of expression differ so much in different languages, that when we attempt to follow literally the expressions of a foreign writer, we are apt to fall into idiomatic phrases, and even palpable absurdities. In translating a book, therefore, from one language to another, it should not be rendered word for word, but idiom for idiom; though we are bound to adhere with fidelity to the ideas of the author, yet it is equally important that we should endeavour to strip the work of its foreign costume, and of the stiffness and constraint which, with every attention, translations almost always possess; in a word, it should be our object to *naturalize* it. A neglect of this is the prevailing defect of translations, and is, probably, the reason that they are seldom read with interest or improvement, and that so few works of merit are transferred successfully from one language to another.

These are the maxims which the translator has endeavoured to pursue in the following work, though he is conscious of having fallen very far short of them. The original is remarkable for the conciseness and perspicuity of its style, and the admirable arrangement of its matter; it is perhaps the most finished specimen of the inductive philosophy in the circle of the medical sciences. He thought that he could not more effectually promote the study of this interesting science, or present a better model for investigating the medical sciences, generally, than by the following, which he trusts will be found a faithful, though not servile translation. He has with this view adopted the technical names, weights and measures, most familiar to the American student.

Balt. *Aug.* 1823.

PREFACE.

EVERY natural science exists under two different forms, which may with propriety be denominated systematic and theoretic.

The first has for its foundation certain gratuitous suppositions, or assumed principles, to which known facts are applied in such a manner as to explain them. Should any new phenomenon be observed which does not agree with the fundamental principles of this system, the *fact* must be so modified that an explanation of it may be given. If the supporters of systematic science pay any attention to experience, it is with the intention of confirming the system which they have adopted; every thing which tends to overthrow *it* is neglected, at least is not noticed; they endeavour to find nature as it should be, according to their preconceived opinions, not as it is—in a word, they follow the synthetic method; descending from hypothesis to facts, without paying any attention to those general principles which we ought always to keep in view, in our search after truth. It is scarcely possible, that under this form natural science should make any real progress.

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Under the influence of the *theoretic* mode, the natural sciences assume an aspect entirely the reverse. Under it, facts,—*facts alone*, serve as the foundation of science. The object of its followers is to verify, and multiply them as much as possible; and afterwards to study carefully the phenomena which they exhibit, and the laws by which they are governed. When a person gives himself up to experimental researches, it is to augment the number of ascertained facts, or to discover their reciprocal relations. In a word, he follows the analytic method: the only guide which conducts us directly to truth. By this method the sciences are improved, if not more rapidly, with at least more certainty, and we may hope to see them approximate perfection.

The physical sciences, with scarcely a single exception, were systematic until the time of Galileo and Bacon. From that period, and in a great degree from the influence of the writings of the illustrious Bacon, they have undergone a most salutary change. From being systematic and synthetic, they have become theoretic and analytic; and from that period their march towards perfection has been extremely rapid.

It is unpleasant, but at the same time it is necessary, to remark, that in the midst of this general progress of the sciences, physiology, that important branch of human learning, still retains the systematic form. If any one will take the trouble to examine with attention, the manner in which it is presented in the works of the most approved authors, he will find that it rests entirely on simple suppositions, to which each one has in his turn attached some of the numerous phenomena of life, thinking he has thus given a satisfactory explanation of them. What, for example, are *"the vital and animal spirits"* of the ancients; *"the Faculties"* of Galen, *"the moving and generative principle,"* of Aristotle, *"the archeus," "vital properties,"* &c. which have been successively adopted to explain the functions of animal life, but arbitrary suppositions which have served a long series of generations to conceal that absolute ignorance which has heretofore, and will perhaps always exist, concerning *the cause of life?*

What is the consequence of all this?—It is that physiology, brilliant as it appears in our modern treatises, and notwithstanding the supposed improvements which it has derived from the talents of many distinguished men, is a science still in its infancy.—It is absolutely necessary to do something to remove from it this reproach. The first step to be taken in accomplishing this object is, to change the method which has been heretofore pursued. It must be made to assume the analytic method, and theoretic form. This is indispensable to put it in the way of improvement, and to place it on a level with the more advanced of the physical sciences.

My principal aim in this work is, to contribute something towards the accomplishment of this important change. I have endeavoured, as far as possible, to present the science in the theoretic form, following the analytic method in the explanation of facts.

One will especially find in this book facts, the truth of which I have done all in my power to establish as definitely as possible, by observations upon man in a healthy or morbid state, or by experiments upon living animals. Among these experiments a considerable number will be found new.

I have not however neglected the possible and useful application of physical, mechanical and chemical principles to the phenomena of life. Perhaps the application may be found somewhat different from what has been heretofore proposed, for I have taken every care to arrive at the greatest possible degree of exactness. Human physiology is the only subject which I have pretended to treat. Physiology, which in its more enlarged meaning, comprehends the history of all living beings, animal and vegetable, is not sufficiently advanced to be formed into a complete system; and what is known, it would not be proper to introduce into a work *professedly elementary*.

In concluding, it is proper to remark, that this book is solely designed for students in medicine. If they find here, in terms clear and simple, all which is positively known of physiology, I shall have accomplished the object which I have proposed to myself.

Note.—I am desirous of expressing publicly my thanks to my friend Doctor Edwards, who has assisted me in all my experiments, and whose learning and judgment have been a very great benefit to me in the preparation of this work.

A

SUMMARY

OF

PHYSIOLOGY.

General physiology is that natural science, which has for its object a knowledge of the phenomena which are peculiar to living bodies. It may be divided into *vegetable physiology*, which is confined to vegetables, *comparative physiology*, which treats of animals, and human physiology, the particular object of which is man. It is of this last that we propose to treat in the following work.

PRELIMINARY OBSERVATIONS.

Of Substances and their Divisions.

The term substance, or body, may be applied to every thing which is capable of acting upon our senses. Substances are divided into ponderable and imponderable. The first are those which act on many of our senses, and the existence of which is therefore clearly demonstrable, as solid, liquid, and gaseous bodies. The second are those which do not act in general upon more than one of our senses, the existence of which has not been demonstrated, and which may, perhaps, be but a modification of other bodies, such are caloric, light, the electric and magnetic fluids. Ponderable substances are indued with common, or general, and particular or secondary properties. The general properties of substances are extension, divisibility, impenetrability, and mobility. A ponderable body possesses always these four properties united. The secondary properties are different, in different bodies, such as hardness, porosity, elasticity, fluidity, &c.; they, together with the general properties, constitute the state of the body. It is in acquiring, or losing these secondary properties that bodies change their state. e. g. Water may exist under the form of ice, liquid, or vapour, although it is still the same body. To appear successively under these three different forms, it is only necessary that they should acquire or lose some one of these secondary properties.

Substances are simple or compound. Simple substances occur rarely in nature, but are almost always the product of art; indeed they are only called simple, because no artificial means have been discovered of decomposing them. The following are the names of bodies at present considered simple, viz: Oxygen, chlorine, iodine, fluorine, sulphur, hydrogen, aluminium, yttrium, glucinium, magnesium, zinc, iron, tin, arsenic, molybdenum, chromium, tungstenium, antimony, uranium, cerium, cobalt, titanium, bismuth, copper, tellurium, nickel, lead, mercury, osmium, silver, rhodium, palladium, gold, platina, iridium, borium, carbon, phosphorus, azote, silicium, zirconium, columbium, strontium, barium, sodium, potasium, manganesium, calcium.

Compound substances are found every where; they form the mass of this globe, and of almost every thing which we see upon its surface. There are some substances, the composition of which does not undergo any spontaneous change; there are others, a change in the composition of which is constantly taking place. This constitutes a very important difference in bodies; they are thus very naturally divided into two classes. Those substances, the composition of which remain constantly the same, are called *dead*, *inert*, *inorganic bodies;* those on the other hand, the elements of which are continually varying, are called *living*, *organized bodies.*

Organic and inorganic bodies differ from each other in the three following respects, viz.—First in form, second in composition, third, in the laws which govern their changes of state. The following table exhibits the most remarkable differences.

Differences between dead, inorganic, and living organized bodies.

FORM.

	Inorganic bodies.	Living bodies.
	Form angular. Volume indeterminate.	Form rounded. Volume determinate.

COMPOSITION.

	Inorganic bodies.	Living bodies.
	Sometimes simple. Rarely formed of more than three elements.	Never simple. Having at least four elements, often eight or ten.
	Constant.	Variable.
	Each part can exist independent of the rest.	Each part more or less dependent on the rest.
	Capable of being decomposed and restored.	Capable of being decomposed, but not of being restored.

LAWS WHICH GOVERN THEM.

	Inorganic bodies.	Living bodies.
	Entirely submissive to the laws of attraction, and chemical affinity.	Partly submissive to attraction and chemical affinity. Partly governed by an unknown power.

Living bodies arrange themselves into two classes; the one includes vegetables and the other animals.

Differences between vegetables and animals.

VEGETABLES.	ANIMALS.
Are fixed to the soil.	Have the power of locomotion,
Have carbon as the principal base of their composition.	Have azote for the base of their composition.
Composed of four or five elements.	Often composed of eight or ten elements.
Receive from around them their aliment ready prepared.	Are compelled to act upon their aliment to render it suitable to nourish them.

Elements which enter into the Composition of Animal Substances.

A consideration of the elements which enter into the composition of animal bodies, is not alone interesting in a physiological point of view, but furnishes still more important assistance to the physician in the treatment of diseases. These elements consist of solid, fluid, gaseous, and unconfinable bodies.

The Solid Elements.

Phosphorus, sulphur, carbon, iron, magnesia, lime, soda, manganese, potash, silex, and alumine.

The Fluids.

Muriatic acid, water, which in this case may be considered an element, constitutes three, out of four parts, in the organization of animal bodies.

Gaseous Elements.

Oxygen, hydrogen, and azote.

Unconfinable Bodies.

Caloric, light, electric fluid and magnetism. These different elements, being combined according to certain laws, at present unknown, form what may be called the immediate materials of animals.

Immediate Materials of Animals.

These are distinguished into azotic, and non-azotic. The azotic principles—are, albumen, fibrine, gelatine, mucus, caseous matter, urea, uric acid, osmazome, colouring principle of the blood. The non-azotic principles—are, acetic acid, benzoic acid, lactic acid, formic acid, oxalic acid, rosacic acid, the sugar of milk, the sugar in diabetes, picromel, the yellow colouring principle of the bile, and other fluids or solids which become yellow accidentally, the vesicating principle of cantharides, spermaceti, biliary calculi, odoriferous principle of amber, musk, castor, civet, &c. of which but little is known but their power of acting on the sense of smell. The adipose substance of animals is not an immediate simple principle. M. Chevreuil has proved that the adipose substance found in the human subject, the hog, and sheep, is principally formed by two fatty bodies, which present very different characters, and which may be easily separated. The butter from the cow is not a simple body; it contains acetic acid, a yellow colouring principle, and an odoriferous principle, which manifests itself in caseous matter in a state of fermentation. Adipocere—a natural substance found in dead bodies which have been long buried, cannot be reckoned among the number of these immediate materials. It is composed of margarine, acid of fat, a yellow colouring principle, and an odoriferous principle. This substance must not be confounded with the spermaceti of the whale, or biliary calculi, both of which differ essentially from it. M. Chevreuil has shewn that it does not contain a single principle analagous to them.

Organic Elements.

These materials combine together, and from their combinations arise the organic elements; which are either solids, or fluids. We are entirely ignorant of the laws, or forces, by which these combinations are effected.

Organic Solids.

The solids assume the form of tubes, plates, scales, or membranes. In man, the total weight of the solids is, in general, eight or nine times less than the fluids; this proportion varies however according to circumstances.

The ancients believed that all the organic solids of the body might be traced back to a simple fibre, which they supposed was formed of earth, oil, and iron. Haller, who admitted this idea of the ancients, acknowledges that it is only perceptible to the mind's eye: "*Invisibilis est ea fibra; sola acie mentis distinguimus,*" which is much the same as to have said that it did not exist at all; a thing of which, at the present day, no one doubts. The ancients likewise admitted secondary fibres, which they supposed were formed by particular modifications of the simple fibre; as the nervous, muscular, parenchymatous, and osseous fibres. Professor Chaussier has lately proposed to admit four kinds of fibres; which he distinguishes by the names of laminer, nervous, muscular, and albugineous.

The science was in this state, when M. Pinel conceived the happy idea of distinguishing the organic solids, not by fibres, but by tissues or systems.* He founded upon this distinction various orders of diseases, particularly the phlegmasiæ. Bichat availed himself of this ingenious idea, and applied it to all the solid parts of the animal body. Those parts of his works which relate

* The English assert that this idea was first suggested by Dr. Carmichael Smith in 1788, in a dissertation read before a society in London.—*Trans.*

to this subject may be accounted among his strongest claims to eminence.* M. Dupuytren perfected the classification of Bichat; M. Richerand has likewise pointed out many of its imperfections.

The following is the classification of tissues as corrected by Messrs. Dupuytren and Richerand:

1	Systems.	cellular.	
2		vascular.	arterial. venous. lymphatic
3		nervous	cerebral. of the ganglions.
4		osseous.	
5		fibrous.	fibrous. fibro-cartilaginous. dermoide.
6		muscular.	voluntary. involuntary.
7		erectile.	
8		mucous.	
9		serous	
10		horny, or epidermic.	pilious. epidermic.
11		parenchymatous.	glandular.

These different tissues, together with the fluids, compose the organs or instruments of life. When several organs, in their action, tend to one common end, they may together be called an *apparatus*.† The number of these and their arrangement constitute the differences between animals.

Properties of the Tissues.

The tissues which compose the organs possess certain physical and chemical properties, which it is important to study both in the dead and living animal body. Nearly all the physical properties which are found in inorganic substances will be found in them; different degrees of consistency, from extreme hardness to a consistency almost fluid, elasticity, transparency, and refrangibility; but our attention is particularly attracted by certain properties, which have been called the *properties of tissues;* such are their extensibility, and contractility of tissue, and contractility from exposure to heat, (*par racornissement.*)

* See Traite de l'Anatomie Generale.

† There is no term, in English, which perfectly expresses the idea conveyed by the French word "*appareil.*" I have selected the word apparatus as approaching nearest to it.—*Trans.*

Independently of their physical properties, the tissues have been examined as it respects their composition; and it has been found that some of them are chiefly composed of gelatine, others of albumen, some of phosphate of lime, others of fibrine, &c. These different tissues also present, in the living body, certain phenomena, which have attracted the attention of physiologists. One branch of science is devoted to the investigation of these tissues, under the threefold consideration of their physical, chemical and vital properties; this is called general anatomy, the study of which is of the highest importance to physiology.*

Of the Fluids or Humours.

The fluids of animal bodies, especially man, greatly exceed the solid parts. In the adult, they are as nine to one. Professor Chaussier placed a body, weighing one hundred and twenty pounds, in an oven; after being allowed to dry for several days, it was found to be reduced to twelve pounds. It has been long remarked, that dead bodies which have been found, after having been long buried in the burning sands of Arabia, have undergone an astonishing diminution of weight. The animal fluids are sometimes contained in vessels, in which they move with a greater or less degree of rapidity, sometimes in spaces where they seem to be deposited, at others in large cavities, where they remain for a longer or shorter time.

The fluids of the human body, which constitute a principal object in our present inquiry, are

1. The blood.
2. The lymph.
3. The perspiratory fluids;—which comprehend cutaneous transpiration, the transpiration of the mucous, serous, and synovial membranes, the cellular, adipose, and medullary membranes, and the interior of the thyroid and thymus glands, &c.
4. The follicular fluids;—The fatty humour of the skin, the cerumen, the sebaceous humour of the eye-lids, the mucus of the mucous glands and follicles of the tonsils, the cardia, and parts about the anus, and prostate, &c.

* See General Anatomy of Bichat.

5. The glandular fluids;—The tears, the saliva, the pancreatic juice, the bile, the urine, the fluids of the glands of Cowper, the semen, the milk, the fluid contained in the capsulæ renales, and the contents of the mammæ and testicles in new born children.

6. The chyme and the chyle.

The physical and chemical properties of the fluids are very various. Many resemble each other, but no two are precisely alike. At all times, great importance has been attached to a methodical arrangement of them, and we find that different classifications have been adopted, according to the prevailing doctrines of the schools at different periods. Thus, the ancients, who laid great emphasis on the influence of the four elements in the operations of nature, asserted, that there were four principal humours in the body, viz. the blood, the lymph, the yellow and the black bile; and that these four humours corresponded to the four elements, the four seasons of the year, the four parts of the day, and the four temperaments.

In more modern times, other divisions have been substituted for this classification of the ancients. Thus, they were at one time divided into three classes, viz. 1st, the chyme and chyle; 2nd, the blood; 3d, the humours secreted from the blood. Some authors have thought it sufficient to arrange them into two classes. 1st, fluids which are useful as aliments; 2d, those which are useless in this respect. The first are called *recrementitial*, that is, humours which after their formation are destined to nourish the body; the second, *excrementitial*, or those which are thrown out of the economy; those humours which participate in these two characters, have for this reason received the appellation of *excremento-recrementitial.* Chemists have lately endeavoured to classify the humours according to their peculiar nature; as the albuminous, fibrous, and aqueous humours, &c. But the classification of Professor Chaussier will be found to be the best. This has no regard to the nature of the fluids, or the uses to which they are destined, but is founded on the mode of their formation, the only character which remains always the same. This is the classification that we have followed in the enumeration of the fluids.

Causes of the Phenomena peculiar to Living Bodies.

From the earliest antiquity it has been observed, that the greater number of the phenomena which take place in living bodies, are essentially different from those that occur in dead, inorganic matter. One particular cause has been assigned to explain the phenomena observed in living bodies. This cause has received different names. It was denominated by Hippocrates, φυσις (nature;) by Aristotle, *moving and generative principle;* by Boerhave, *impetum faciens;* by Van Helmont, *archea;* by Staal, *soul;* others again have called it *vis insita, vis vitæ,* &c. M. Chaussier, in his learned lectures, and in his synopsis of the characters of vital power, has adapted the name "*force vitale*."*—It is not worth while to endeavour to deceive ourselves by this expression, "*force vitale*," or vital power. It does not and cannot mean any thing else than the *unknown cause* of vital phenomena.

In the same manner, says these physiologists, as attraction presides over the changes of state in dead matter, does the vital power control the modifications of organized bodies. But they fall into an error, for vital power and attraction cannot well be compared to each other; the laws of this last are perfectly known; those of vital power entirely unknown. Physiology is, at this time, precisely in the state in which the physical sciences existed before the discoveries of Newton; and it requires a genius of the highest order to discover the laws of vital power, in the same manner as Newton made known those of attraction. The glory of this great man does not consist in having discovered attraction, as some believe, for before his time this cause was known, but in having shown that this power "acts directly in proportion to the mass, and inversely as the squares of the distances."

Vital properties.

It has not been supposed sufficient to admit the existence of this vital power, and to allow it to play an important part in the explanation of vital phenomena; but it is asserted that this power manifests itself by the *vital properties;* and on this, some authors have founded not only physiology, but pathology, and therapeutics.

* See the Synoptic Table of the Fluids.

These vital properties, the existence of which has been generally admitted, have received different names; they have been called, viz.

1. Organic, nutritive, vegetative, and molecular sensibility.

2. Organic insensible contractility, nutritive and fibrous contractility, tone, tonicity.

3. Cerebral, perceptive, and animal sensibility, and sensibility of relation.

4. Organic sensible contractility, irritability, and vermicular motion.

5. Voluntary and animal contractility, contractility of relation, &c.

With respect to these properties, some are common to all living bodies; others are peculiar to certain parts of animals only.

The first alone deserve the name of vital properties. It is essential, however, to remark, that organic sensibility, and organic insensible contractility, do not fall under the cognizance of the senses. These are evidently mere suppositions, or modes of conceiving and explaining the phenomena of life. They do not in reality exist, although their existence seems to be universally taken for granted. Many persons are in the habit of speaking of the alterations which these vital properties undergo, and of the necessity of bringing them back to their natural state. It has even been attempted to classify the articles of the materia medica, according to their supposed effects upon these properties; and many physicians treat disease according to this doctrine. This is evidently wrong.

There are others of these properties which are peculiar to certain animals, or only to particular parts of them. Organic sensible contractility is an example of this, which exists in the heart, intestinal canal, and bladder, &c. but is not observed in any other part of the animal economy. Cerebral or animal sensibility, as it is called by Bichat, and voluntary contractility, can only be reckoned among the vital properties by an abuse of terms. It is plain that these are but *functions*, or the results of the action of several organs, which in acting have one common aim. We shall say nothing of the *vital power of resistance*, of *vital affinity*, *fixed situation*, *caloricity*, &c. because these different properties, although proposed by men deservedly distinguished, have not received the general assent, nor can we perceive any necessity for admitting them.

Our views, then, concerning the vital properties are such, that we are induced to reject organic insensible contractility, and organic sensibility, as useless and dangerous suppositions; to consider organic sensible contractility as the action of an organ; and voluntary contractility, as well as cerebral sensibility, mere functions.

Phenomena of Life in the Fluids.

The doctrine of the vital properties has not been applied to the fluids, though it is admitted that they possess life. A method much more philosophical has been pursued with respect to the fluids than the solids; for it was not admitted that they were endowed with life, until this was proved by the sensible phenomena which they exhibit. Thus their vitality is inferred from their preserving their fluidity, while they remain in certain parts of the living body; and from the manner in which some of them organize themselves, when they are thrown out of the vessels; and their power of evolving caloric. These are the chief phenomena which, according to modern physiologists, prove that the fluids are endowed with life. It should however, be recollected, that all the fluids do not possess these characters. The blood, chyle, lymph, and a few other fluids destined to nourish the body, alone present them. The excrementitial fluids, such as the bile, urine, cutaneous transpiration, &c. do not present any phenomena which are analagous to them; what is therefore said of the vitality of the fluids, cannot be understood as applying to these last.

Before beginning the examination of the phenomena of life in man, the principal object of this work, we will make one general remark. Whatever may be the number and diversity of phenomena presented by man during life, they may be reduced at last to these two principal ones, viz. *nutrition and vital action.* A few words respecting each of these phenomena are indispensable to the proper understanding of those subjects which will hereafter fall under our consideration.

The life of man, and that of other organized bodies, is preserved by the habitual assimilation of a certain quantity of matter, called aliment. If they are deprived of this for a given period, it will be necessarily followed by a cessation of life. On the other hand daily observation shews, that the organs of man, and other living beings, are constantly losing a certain portion of the matter of which they are composed. A necessity, therefore, for repairing the loss which is thus constantly sustained, is the reason why the habitual use of aliments is required. From these data, and from some other circumstances, which we shall mention by and by, it has been justly concluded, that living bodies are not composed, identically, of the same matter at every period of their existence, but that they undergo a total renovation. The ancients imagined that this was accomplished in the space of seven years. But, without admitting this conjecture to its full extent, it is extremely probable that all parts of the body, during life, are undergoing a change, which has the double effect of expelling those molecules which have served their appointed time in the composition of the organs, and of replacing them by new molecules. It is this which constitutes nutrition. This process does not fall, indeed, under the cognizance of our senses; but the effects are so palpable, that it would be the height of scepticism to doubt it. In the present state of physiology, this operation cannot be attributed to chemical affinity, that power which controls the action of minute particles of matter upon each other in dead bodies, nor, indeed, do we know of any satisfactory explanation of it. To say that it depends on *organic sensibility*, or *organic insensible contractility*, or simply on *vital power*, is only to express the fact in different terms, without giving any explanation of it. But however this may be, we can only attribute to this process of nutrition, the power of living bodies to preserve or change the physical properties of their organs. Our different organs being found to present different physical properties, the process of nutrition must no doubt vary in each.

Independently of the physical properties which all parts of the body present, there are a considerable number which exhibit, either continually or periodically, a phenomenon which has been called *vital action*. The liver, for example, is endued with a peculiar power by which it is enabled constantly to form a fluid called bile; the same remark may be applied to the kidneys in the formation of urine. The voluntary muscles under certain circumstances, grow hard, change their form, and contract; this is another example of vital action. These vital actions are of great importance in the life of man, and other animals, and particularly demand, therefore, the attention of the physiologist.

Vital action evidently depends on nutrition, and nutrition is reciprocally influenced by vital action. Thus an organ which ceases to receive nutrition, soon loses its power of vital action; and organs, the action of which is frequently repeated, possess more active powers of nutrition, while in those, on the other hand, which act but little, the process of nutrition is evidently slow.

The precise mode in which vital action is performed, is unknown. There takes place in the organs, some insensible movement of its molecules, which can no more be explained than the process of nutrition. No vital action, however simple it may appear to be, can be considered an exception to this rule.

All the phenomena of life, therefore, may be included under these two heads, viz. *nutrition and vital action;* but, as the peculiar action of the particles, which constitute these two phenomena, cannot be perceived by our senses, this is not a point upon which we can profitably bestow much attention. We must content ourselves with investigating their results; that is, the physical properties of the organs, the sensible effects of the vital actions, and the manner in which these concur in the general processes of the living body. This is, in fact, the end of physiology, and, to attain this end, the phenomena of life have been divided into different classes, or functions.

Authors have differed much in their classifications of the functions. Without stopping to enumerate the different classifications that have been adopted at different epochs of science, which does not comport with the nature of this work, we shall divide the functions, 1st, into those which connect the individual with surrounding objects; 2nd, those of nutrition; 3rd, those which have for their aim the reproduction of the species. We may call the first, *functions of relation;* the second, *functions of nutrition;* and the third, *functions of generation.**

The method to be pursued in the investigation of a function, is

* For the developement of the different systems of classification, see the Physiology of M. Richerand, and the Table of Functions of M. Chaussier. We enter upon the details of this subject in our private lectures.

by no means a matter of indifference. The following is the one which we have adopted.

1. General idea of function.

2. Circumstances which keep up the action of organs, and which we call *excitants of functions*.

3. Concise anatomical description of the organs concurring in any function, and which may be called its *apparatus*.

4. The action of each organ in particular.

5. A summary showing the utility of the function.

6. The relation of the function to the parts before examined.

7. The modifications which the function exhibits, according to age, sex, temperament, climate, season, and habit.

OF THE

FUNCTIONS OF RELATION.

The functions of relation include, *sensation*, *intelligence*, *voice*, and *motion*.

OF THE SENSATIONS.

Sensations are those functions which are destined to receive impressions from external objects, and to convey them to the sensorium. These functions are five in number, viz. *seeing*, *hearing*, *smelling*, *tasting*, and *feeling*.

OF VISION.

Vision is the function by which we become acquainted with the size, figure, colour, and distance of bodies, &c. The organs which compose the *apparatus of vision*, act under the influence of a particular excitant, called *light*. We perceive bodies, and become acquainted with many of their qualities, although they may be at a considerable distance from us; there must, therefore, be some intermediate agent between these objects and our eye; this agent is *light*. Light is an exceedingly subtle fluid, which emanates from a class of bodies called luminous; as for example, the sun, fixed stars, ignited substances, and those that are called phosphorescent. Light is composed of particles which move with a prodigious velocity. It is ascertained that it moves at the rate of eighty thousand leagues in a second. A *ray of light* is a series of particles succeeding each other, without interruption, in a right line. The particles which compose a ray, are separated from each other by considerable intervals, relatively to their masses. This may be shewn by making a large number of rays cross each other at any given point, when it will be perceived that the particles do not strike against each other in meeting.

Light, in passing from luminous bodies, forms diverging cones, which, if they meet with no obstacles, are prolonged indefinitely. Natural philosophers have inferred from this, that the intensity of light received from a luminous body in any given spot, is in an inverse ratio to the squares of the distances of the surface of the luminous body from which it arises. The cones, formed by light in passing from luminous bodies, are generally called a *pencil of rays*. Those bodies which transmit the light are called *media*. When light meets in its progress certain bodies, called opaque, it is turned from a right line, and the direction given to it is modified by the disposition of the surfaces of those bodies. The change of direction, which the light undergoes in this case, is called *reflection*. This branch of physics has received the name of *catoptrics*.

Certain bodies transmit light, or suffer it to pass through them; for example, glass. These are said to be *transparent*, or *diaphonous*. In passing through them, the light undergoes a certain change, called *refraction*. As the mechanism of the organ of vision, from its structure, depends entirely upon the principles of refraction, it will be necessary to stop for a moment, for the purpose of examining the subject.

The point at which a ray of light enters a medium, is called the *point of immersion*; and that from which it passes out, the *point of emergence*. If a ray enters perpendicularly the surface of a medium, it passes through the medium preserving its first direction; but, if it strikes obliquely to the surface of the medium, it is turned from its course at the point of immersion.

The angle of incidence is that contained between the incident ray, and a line drawn perpendicularly to the surface of the medium, from the point of immersion. The angle of refraction is that contained between the line described by the refracted ray, and a line perpendicular to the refracting surface at the point of immersion.

A ray of light passing from a rarer into a denser medium, is refracted towards a perpendicular to the surface of the denser, drawn from the point at which the ray meets the medium; but, on the contrary, in passing from a denser into a rarer, it is refracted from the perpendicular. When a ray of light passes from a rarer through a denser medium, the two surfaces of which are parallel, the ray, in passing into the surrounding air, will take a direction parallel to that of the incident ray.

Bodies refract light, in proportion to their density* and combustibility. Thus, if two bodies be of equal density, but one more combustible than the other, the refractive power of the first will be found greater than that of the second. All diaphonous bodies, at the same time that they refract light, reflect it. In proportion as bodies possess this last quality, they are capable of being used as mirrors. When they have but little density, as for example, the atmospheric air, they are only visible when they exist in considerable volumes.

The form of refracting bodies has no influence upon their refracting power; but it modifies the disposition of the refracted rays with respect to each other. The perpendiculars at the surface of the refracting body approaching or separating from each other, according to the form of the body, the refracted rays must also converge or diverge from each other. When, from the form of a refracting body, the rays are made to converge, the point where they unite is called *the focus of the refracting body.* Bodies of a lenticular form, or those bodies which are terminated by two segments of spheres, present this phenomenon. A refracting body with parallel surfaces, does not change the direction of the rays, but approximates them towards its axis by a sort of transport. A refracting body with two convex surfaces, called a lens, does not possess a greater refracting power, than a body which is convex on one side and plane on the other, but the point where the rays unite is nearer.

The study of refraction makes us acquainted with an extremely important fact; it teaches us that a beam of light is composed of an infinite number of differently coloured rays, which are differently refrangible; i. e. if the medium and angle of incidence be the same, the refraction of the rays differ with their colour. If, in a room previously darkened, we allow a beam of light to pass through a small aperture, so that it will traverse a prism of glass, or any other refracting body, the surfaces of which are not parallel, and if this be received on any plain surface, as for example, a sheet of paper, it will be seen that the

* Density is the relation of weight to volume. If all bodies were of the same volume, their relative density might be determined by their weight.

beam occupies a considerably larger space than the size of the aperture, of an oblong form; and, instead of producing a white image, a considerable number of different colours will be observed, which run insensibly into each other, and among these may be distinguished the seven following colours, viz. red, orange, yellow, green, blue, indigo, and violet. Neither of these colours are capable of being decomposed; they are together called the *solar spectrum*. Light is not, therefore, homogeneous, but is composed of very differently coloured rays. On this fact is founded the explanation of the different colours of bodies. A white body reflects light without decomposing it; a black body does not reflect light, but totally absorbs it; coloured bodies decompose light and reflect it; they absorb some of the rays and reflect others. Thus a body will appear red, when the red rays are alone reflected and the rest absorbed; or will appear green, when the union of the colours reflected form green. Transparent bodies also appear coloured from the light which they refract, and when seen by refraction, they appear of a colour different from what they seemed by reflection. If, now, it be inquired, why certain bodies reflect one ray and absorb another? It will be replied, that this phenomenon arises from the peculiar arrangement of the particles of which the body is composed.—This explanation resembles very much what has been given of the phenomena of life, of which we have before spoken; that is, it is very well as far as it goes, but, in fact, it explains nothing. The discovery of the action of refracting bodies upon light, has not been a mere object of curiosity; but has led to the construction of ingenious instruments, by means of which the sphere of human vision has been astonishingly extended.

Apparatus of Vision.

The *apparatus of vision* is composed of three distinct parts. The first modifies the light, the second receives the impression of this fluid, and the third transmits this impression to the sensorium. The structure of this organ is extremely delicate. Nature has taken therefore great care to place before it various parts, which protect and preserve it in a condition necessary to the free and easy exercise of its functions.

The protecting parts are the eye-brows, the eye-lids, and the apparatus for the secretion and excretion of the tears.

The eye-brows are peculiar to man, and are formed,

1. By hairs of various colours.
2. By skin.
3. By sebaceous follicles placed at the root of each hair.
4. By muscles destined to move it, viz. the frontal portion of the *occipito-frontalis*, the superior edge of the *orbicularis palpebrarum*, and the *corrugator supercilii.*
5. By numerous blood vessels.
6. By nerves.

Uses of the eye-brows.—The eye-brows have various uses. The projections which they form, protect the eyes from external violence. The hairs, from their oblique direction, and from the oily substance with which they are covered, prevent the sweat from running into the eye, and irritating the surface of the organ; they direct it towards the temple and root of the nose. The colour and number of the hairs of the eye-brows have some influence upon their use. These are found to have some relation to the climate. The inhabitants of warm climates generally have them very thick, and very black. The inhabitants of cold regions may have them thick, but they are seldom black. The eye-brows guard the eye from the too vivid impression of light, particularly when they are drawn together, as in the act of frowning.

The eye-lids are two in number in man, and are divided into superior and inferior; or great and small; *palpebra major and palpebra minor.* The form of the eye-lids is accommodated to that of the globe of the eye, so that when they are brought together, they completely cover the anterior surface of that organ. They do not meet on a level with the transverse diameter of the eye, but considerably below it; this was therefore falsely called by Haller *æquator oculi.* The more extended the opening that separates the eye-lids, the larger the eye appears; the opinion we form of the size of the eye is often, therefore, very incorrect. The open edge of the eye-lids is thick, firm, and furnished with hairs, more or less numerous, which are, generally, of the same colour with the hair of the head. These hairs are placed very near to each other. Those of the superior eye-lid form a slight curve upwards, but those of the inferior eye-lid turn in an opposite direction. When they are very numerous and very long, they are considered beautiful; an idea which agrees very well with the utility resulting from them. The eye-lashes are covered with an unctuous substance, derived from the small follicles situated in the thickest part of the eye-lids, near the roots of the eye-lashes. They have these in common with the hair in most parts of the body. Between the line occupied by the eye-lashes and the internal surface, there is a smooth edge where the eye-lids touch each other. This may be called the *margin of the eye-lids.*

The eye-lids are composed of a muscle with semicircular fibres, the *orbicularis palpebrarum*, of a cartilage, of a ligament, the *large ligament of the eye-lid*, of a great number of sebaceous follicles, *meibomian glands*, and of a portion of mucous membrane. All these parts are connected together by cellular membrane, generally loose and fine, and containing no fat. The skin of the eye-lids is very fine and semi-transparent; it adapts itself readily to their movements, and presents transverse folds. The muscle of the eye-lids, by its contraction, approximates them, or, as we commonly express it, shuts the eye, at the same time that it presses the eye-lids a little upon the globe of the eye.

The cartilages of the eye-lids are called *tarsi.* That of the superior is much larger than the inferior; their use is to keep the eye-lids extended, and constantly accommodated to the form of the eye; besides, they support the eye-lashes, afford a suitable situation for the meibomian glands, and serve to protect the eye from external injury. The use of the tarsi, as respects the motion of the eye-lids, does not appear indispensable, as they are not found in many animals, the eye-lids of which, nevertheless, perform their functions well. The large ligament is nothing more than the cellular membrane which passes from the base of the orbit to the superior edge of the cartilage of the tarsus. It seems intended to limit the motion by which the eye-lids approach each other.

The cellular tissue of the eye-lids is extremely fine and delicate, and contains no fat, but is filled with a very thin serum, which in some cases has a greater degree of consistence, and accumulates in the cells of this tissue; when this is the case, the eye-lids become distended, and of a bluish colour. This colour and swelling of the eye-lids is frequently observed after excesses of every kind, after severe diseases, during convalesence, and in women during menstruation, &c. The fineness and laxity of the cellular membrane of the eye-lids, and the absence of fat from its cells, are necessary for their free motion. The internal surface of the eye-lid is covered by a mucous membrane. Besides the parts already mentioned, the superior eye-lid has a muscle proper to it, this is called the elevator palpebræ superioris.

Uses of the eye-lids.—The eye-lids cover the eye during sleep, and preserve it from the contact of foreign bodies which float about in the atmosphere; they preserve it from blows, by their instantaneously closing; by habitually closing, at nearly regular intervals, they prevent any bad effect from the long continued contact of the air, and have likewise the power of moderating the effect of a too brilliant light. By closing together, they only suffer such a quantity of light to pass, as may be necessary for vision; but not sufficient to injure the eye. On the other hand, when the light is weak, we separate the eye-lids widely, so as to permit the largest quantity of light possible, to penetrate to the interior of the eye. When the eye-lids are near, the eye-lashes form a sort of grate, which only suffers a certain quantity of light to pass at a time. When the eye-lashes are moist, the small drops which cover their surfaces decompose the light in the manner of a prism, and, at the point where the light passes, cause it to appear variegated like the rainbow. The eye-lashes, by dividing the light which penetrates into the eye into pencils, cause ignited bodies to appear, during the night, as if they were surrounded by luminous rays. These appearances vanish as soon as the eye-lid is thrown back, or another direction given to the eye-lashes. It is supposed that the eye-lashes preserve the eye from the atoms of dust which are floating in the air. Vision is always more or less affected in those persons who have lost the eye-lashes.

Glands of Meibomius.—The compound follicles placed in the thickest part of the tarsi, are called the meibomian glands. They are very numerous. There are from thirty to thirty-six in the upper eye-lids, and from twenty-four to thirty in the lower. In each compound follicle there exists a central duct, about which are placed the simple follicles, and into which they pour the matter which they secrete. This duct is always filled with the matter, which, in its ordinary state, is called the meibomian humour, but when it is thick and dry, is called *gum*. After sleep, a certain quantity of this is always found accumulated at the inner angle of the eye, and on the margin of the eye-lids. This matter seems to be of an unctuous nature, but particular researches have induced me to believe, that it is essentially albuminous. Each central duct has an opening, hardly visible, on the internal surface of the eye-lid, very near to the margin.

These openings are close to each other, and range along the whole length of the margin. The meibomian humour passes out through these openings, when we compress the eye-lids lightly; as they experience a sensible pressure on closing the eye-lid, it is probable that this pressure contributes to the excretion of the humour. The principal use of this humour seems to be, to diminish the friction of the eye-lids on the globe of the eye. As the upper eye-lid has a greater extent of motion, and will of course produce more friction, it requires a greater number of these follicles.

Apparatus for the Tears.

The duty of guarding the eye, and preserving it in a condition necessary for the performance of its functions, is not confined exclusively to the eye-brows or eye-lids. There is likewise to be reckoned among the *tutamina oculi*, a small secretory apparatus, of which the mechanism is very curious, and the utility very great. This is the secretory apparatus of the tears. It is composed of the lachrymal gland, the excretory ducts, the caruncula lachrymalis, the lachrymal ducts, and the nasal duct.

Lachrymal gland.—In the small fossa, formed at the anterior and outer part of the arch of the orbit, is placed the lachrymal gland; it is small, and serves to secrete the tears. This gland was known to the ancients, and was called by them the *glandula superior innominata*, in opposition to the *caruncula lachrymalis*, which they called the *glandula innominata inferior*. They attributed the formation of tears partly to the caruncula and partly to a gland that does not exist in man, but is found in certain animals, this is the *gland of Harderus.*

Excretory ducts of the lachrymal gland.—These are six or seven in number. They arise from the small glandular bodies that together form this gland. After having passed through the substance of the gland, they enter the conjunctiva, and pierce this membrane very near the cartilage of the upper eye-lid, towards its external extremity. They may be rendered visible by blowing into them, or by raising the upper eye-lid, and compressing the gland, when the tears will be made to pass out of the orifices of the ducts. This may likewise be done by macerating them in water tinged with blood, or by injecting them with mercury. The tears are poured through these orifices, upon the surface of the conjunctiva.

Caruncula lachrymalis,—At the internal angle of the eye is seen a small, projecting, red body, which, when it is of a bright colour, indicates health and vigour; when it is pale, debility and disease; this is the *caruncula lachrymalis.* This small body is composed of seven or eight follicles ranged in a semicircular line, the convexity within; they have each an opening on the surface of the caruncula lachrymalis, and contain a small hair. These openings are so disposed, that they complete, together with the meibomian glands, a circle embracing the whole anterior part of the eye, when the lids are closed.

Puncta lachrymalia.—At the point where the eye-lids leave the globe of the eye to include the caruncula, on the internal surface, near the open edge, on each lid, is seen a small opening, these are the *puncta lachrymalia*, or external orifices of the lachrymal ducts. The *puncta* are always open, with their orifices directed towards the eye. It has been supposed that they possess a contractile power, which may be shown by touching their extremity with a pointed instrument. Though I have often endeavoured, with great care, to distinguish these contractions, yet I have never succeeded. One circumstance should be mentioned which is extremely apt to deceive us. When we unsuccessfully attempt to introduce the *style*, the mucous membrane which covers the puncta becomes soon irritated and swelled, as would occur from the same violence, at any other part, when the opening will of course be diminished. It is necessary to distinguish this phenomenon from a contraction of the part.

The lachrymal ducts arise from the puncta, and terminate in a canal extending from the inner canthus of the eye to the nasal fossæ. The lachrymal ducts are very narrow, scarcely suffering a hog's bristle to pass. They are from three to four lines in length, and are placed in the thickest part of the eye-lid, between the orbicularis muscle and the conjunctiva. They terminate sometimes singly, and sometimes together, in the superior part of the nasal canal.

Lachrycal sac, and nasal duct.—The canal extending from the inner angle of the eye, to the inferior passage of the nasal fossæ, has been improperly divided by anatomists in two parts. This canal is throughout of the same dimensions—there is nothing therefore to justify the distinction that has been made, in calling the upper part the *lachrymal sac*, and the lower the *nasal duct.* This canal is always formed by the mucous membrane of the nasal fossæ, which covers the osseus duct, passes along the posterior edge of the projecting apophysis of the maxiliary bone, and the anterior part of the *os unguis.* Its use is to conduct the tears into the nasal fossæ.

The Membrana conjunctiva.—This should be ranked among those organs which constitute the apparatus for the tears. This is a mucous membrane, which covers the posterior surface of the eye-lids, and is reflected over the anterior surface of the globe of the eye. It is more extensive than the part it covers, and is therefore very favourable to the motion of the eye-lids and the eye. The loose manner in which it is attached to the eye-lids, and the *tunica sclerotica*, greatly facilitates their movements. Whether the conjunctiva passes over the transparent cornea, or stops at the circumference of this portion of the eye, and is then connected with a distinct membrane which covers this portion of the eye, is not yet perfectly decided. The general opinion is, that it covers the cornea, but M. Ribes, a very distinguished and expert anatomist, contends that the cornea is covered by a peculiar membrane, united to the conjunctiva at its circumference, without being a continuation of it. The conjunctiva protects the anterior parts of the eye; it secretes a fluid which mixes with the tears, and appears to have the same use; it likewise possesses the power of absorbing,* and, as it is very smooth and moist, it greatly facilitates the motions of the eye; lastly, it is the part in contact with the air, when it is not covered by the tears, of which we are now about to speak.

Secretion of the Tears, and their uses.

This is not the place where we intend to enter into a minute description of the secretion of the tears, and in what it resembles or differs from other secretions. It is sufficient here to remark, that the lachrymal gland forms them, and that they are poured out, through its excretory ducts, of which we have spoken, upon the conjunctiva, at the outer and superior part of the eye. We shall next inquire how they proceed, when they have arrived at this part. They are poured out, we would observe in the first place, as well during sleep as when we are awake. In this last state, the eye-lids opening and shutting alternately, the conjunctiva is exposed to the contact of the air, and the eye moves continually, neither of which happens during sleep.

Physiologists have supposed that the tears run along a triangular canal, formed to conduct them towards the inner canthus of the eye, where they are absorbed by the puncta. This canal, say they, is formed, first, by the edge of the eye-lids, the surfaces of which being convex, only touch at one point; and, second, by the anterior face of the eye, which completes the triangular cavity. This canal has its external extremity more elevated than its internal. This arrangement, joined with the action of the orbicularis muscle, the most fixed point of which is attached to the projecting apophysis of the os maxillare, directs the tears towards the puncta lachrymalia.

But this explanation is defective; the eye-lids have not a convex edge, at the part where they come in contact with each other, but have plain margins; no such canal, therefore, can exist. Indeed, when we examine the eye-lids at their posterior surface, when they are shut, it is scarcely possible to distinguish the line where they come in contact. But even admitting the existence

* We may poison an animal by applying to the conjunctiva poisonous substances. For this reason we cannot agree with Mr. Adams, the celebrated London oculist, who thinks that the Belladonna may be continually applied to the eye without inconvenience.

of such a canal, it could serve as a duct for the tears, only during sleep, and it would still remain necessary to show, how they are disposed of when we are awake. During sleep, and at all times when the eye-lids are closed, the tears spread by degrees over the whole surface, both of the *ocular* and *palpebral* conjunctiva. They will, of course, pass in the largest quantities to those points where they meet with the least resistance. The direction where the resistance is least, is the part where the conjunctiva passes from the eye to the eye-lids. In this direction they arrive more easily at the puncta lachrymalia. The tears which are spread over the conjunctiva, must become mixed with the secreted fluids of this membrane, and be absorbed together.

But, when we are awake, they do not pass off in this way. That portion of the conjunctiva, which is in contact with the air, allows the tears which cover it to evaporate, and it would become dry, if the moisture were not renewed by the action of winking. This seems to be the principal use of winking. The tears, which thus constantly cover that part of the conjunctiva exposed to the air, give to the eye its polish and brilliancy.

The increase or diminution of the tears influences very much the expression of the eyes. During the excitement of the passions, this is very apparent. In the ordinary state of the secretion of the tears, they do not tend, in any way, to run over the inferior eye-lid. I know not how the idea has arisen, that the meibomian humour is intended to prevent this, except from the supposed analogy of oily substances, which when placed on the edge of a vessel, prevent aqueous fluids from running over, even when they rise somewhat above its level. But I doubt if this humour can have such an effect, as it is soluble in the tears.

The tears which do not evaporate, or are not absorbed by the conjunctiva, are received into the puncta, and conveyed through the nasal duct to the nose. What the power is by which this is effected, is not certainly known. It has been explained on the principle of a syphon, capillary attraction, vital properties, &c. That of capillary attraction is, perhaps, the most probable. The absorption of the tears by the puncta is not very apparent, except when they are very abundant.

Apparatus of Vision.

The apparatus of vision is composed of the eye and optic nerve. The situation of the eye, at the highest part of the body; the capacity in man of discerning, at the same time, with both eyes the same object; the oblique direction of the base of the orbit; the protection afforded to the eye by this cavity, from external injury; the great abundance of adipose substance and cellular membrane, which form an elastic cushion at the bottom of the orbit, &c. are curious and interesting circumstances, which should not be neglected, but which we can only mention in passing.

The eye is composed of many different parts, which perform very different offices in the function of vision. They may be divided into the refracting and non-refracting parts of the eye.

The refracting parts are;—The *transparent cornea* which is convex on one side and concave on the other. In its form, transparency, and mode of insertion, it greatly resembles the crystal of a watch.

The *aqueous humour*, which fills the chambers of the eye, is not a pure watery fluid, as its name implies, but is chiefly composed of water, with a little albumen.*

The *crystalline humour* has been compared to a lens. The comparison is correct, as far as the form is concerned, but is very defective as respects its structure. The crystalline humour is composed of concentric laminæ, which increase in density as you approach the centre, but differ in refrangibility; and it is enveloped in a membrane, which we know, from experience, to be extremely important. On the other hand, we know that a lens is homogeneous throughout, and that its density and refrangibility in all its parts are the same. It has been always remarked, that the convexity of the anterior surface of the crystalline humour, differs considerably from its posterior surface. The last is a part of a sphere, the diameter of which is much less than that to which the anterior surface would belong. It has been generally believed that this humour was composed chiefly of albumen; but, from an analysis lately made by M. Berzelius, it

* According to M. Berzelius, it is composed of water, 98 10; a little albumen; muriates and lactates, 1.15; soda with a substance only soluble in water, 0.75.

appears that it contains none. It is formed almost entirely of water, and a particular substance, which has a greater analogy, in its chemical properties, with the colouring matter of the blood, than with any thing else.

Behind the crystalline is found the *vitreous humour*, which is so called from its supposed resemblance to melted glass.*

Each of the parts, which we have pointed out, are enveloped in an extremely delicate, transparent membrane. Thus, before the cornea is the conjunctiva, behind it the membrane of the aqueous humour, which covers all the anterior chamber of the eye; i. e. the anterior surface of the iris and the posterior face of the cornea. The crystalline is enveloped in its capsule, which adheres, at its circumference, to the membrane which encloses the vitreous humour. In passing from its circumference, over its anterior and posterior surfaces, it leaves between the two lamina an interval, called the *canal of Petit.* It has been generally supposed, that this canal does not communicate with the chamber of the eye; but M. Jacobson asserts, that it presents a great number of small openings, by means of which, according to him, the aqueous humour can enter in, or go out; but I have carefully sought in vain to find these openings.

The vitreous humour is surrounded by a membrane called *membrana hyaloidea.* This membrane not only surrounds the humour, but it is divided into innumerable cells, which are filled by it. It is not necessary to say any thing of the arrangement of these cells, as this is not of importance in investigating the uses of the vitreous humour.

The eye is not only composed of refracting parts, but likewise of others, which have each a peculiar destination.

The *tunica sclerotica* is a strong fibrous membrane, which constitutes the external coat of the eye. Its evident use is to protect the internal parts of the organ; it likewise serves as a place of insertion to the muscles which move the eye.

The *choroid* coat abounds with blood-vessels and nerves; and is distinctly formed of two laminæ. It is covered with a black substance, which evidently performs an important part in the function of vision.

* According to M. Berzelius, it contains water, 98.40; albumen, 0.16; muriates and lactates, 1.42; soda with animal matter soluble in water only, 0.02; total, 100.0.

The *iris* is a small circular part, which may be seen moving behind the transparent cornea. It is of different colours, in different individuals, and is pierced in its centre by an opening, called the pupil, which enlarges and contracts, according to circumstances, which we shall hereafter point out. The *iris* adheres anteriorly, at its circumference, to the sclerotic coat by a peculiar cellular tissue, which is called the ciliary ligament. The posterior face of the iris is covered by a black substance in considerable abundance. Behind the circumference of the iris, are a number of white, radiated lines, which would unite at the centre of the iris, if they were prolonged; these are the *ciliary processes.* Anatomists are not yet agreed as to the nature and uses of these bodies. Some consider them nervous, others muscular, and others again glandular, or vascular. The truth is, at present it is not easy to decide which of these opinions is most probable; and we shall, by and by, see that their use is equally unknown.

The colour of the iris depends on that of its tissue, which is variable, and that of its posterior surface, which is of a deep black, and affects the appearance of its anterior face. In blue eyes, for example, the tissue of the iris is nearly white, but the deep black, on the posterior part, modifies this, and determines the colour of the eyes. Anatomists vary in their opinions of the nature of the tissue of the iris. Some consider it similar to that of the choroid coat; that is, they suppose it to consist chiefly of vessels and nerves; others think they can distinguish a great number of muscular fibres; it has by some been thought a tissue *sui generis;* and by others confounded with the erectile tissue. M. Edwards thinks that he can demonstrate the iris to be formed of four distinct laminæ, of which two are a continuation of the laminæ of the choroid coat, a third pertains to the membrane of the aqueous humour, and a fourth that forms the peculiar tissue of the iris.

Between the membrana hyaloidea and the choroid coat, there is a membrane chiefly composed of nerves. This is known by the name of *retina;* it is nearly transparent, with a very small degree of opacity, of a slight lilaceous tint, and appears to be formed by the expansion of the optic nerve. M. Ribes, however, thinks differently; he supposes it is formed of a distinct membrane, upon which the optic nerve is very freely distributed. He thus establishes an analogy between the retina and the other membranes. There is upon the back part of the retina, about two lines from the optic nerve, a yellow spot, and at the side of this there are several folds. But these appearances are only found in man, and some species of apes. The eye receives a large number of blood-vessels, and many nerves, the greater part of which come from the opthalmic ganglion.

The Optic Nerve.

This is the medium of communication between the eye and the brain. It does not arise from the *thalamus nervi optici*, as many anatomists have thought, but it derives its origin, 1st, from the anterior pair of those tubercles called the *quadrugemini;* 2nd, from the *corpus geniculatum externum*, an eminence found before, and a little to the outer side of these tubercles; 3d, from the laminæ of cineritious substance, placed before the meeting of the optic nerves, and mamillary eminences, and which is known by the name *tuber cinereum.* The two optic nerves approach each other, and seem to be blended together near the superior part of the sphenoid bone. The most careful researches have been made, for the purpose of determining whether they decussate, or are in contact, or if they really intermix with each other; anatomy has not yet settled this question, but pathology furnishes proofs of all these opinions. Thus, when the right eye has been long diseased, the optic nerve of the same side has been known to become diseased through its whole extent. In another case, where the right eye was diseased, the anterior portion of the same side was found in an evident state of disease, and the posterior portion of the left side to present the same appearance. Some have thought, that the crossing of the optic nerves in fishes, removed every doubt on the subject; but this can only be, justly, considered as amounting to a probability.

The optic nerve is not formed of a fibrous envelope, and of a central pulp, as the ancients believed; but it is composed of very fine filaments, placed at the side of each other, and communicating with each other, like other nerves. This arrangement is very evident in that portion of the nerve which extends from the *sella turcica*, to the eye.

Of the Mechanism of Vision.

To facilitate the explanation of the manner in which the light enters the eye, let us suppose a single luminous beam, passing from a point placed at one end of a straight line, which will pass through the anterior-posterior axis of the eye. We perceive at once that there is no other light, but that which falls upon the cornea, that can assist in vision. That which falls upon the white of the eye, the eye-lashes, or the eye-lids, can evidently contribute nothing to this effect. It is reflected differently, from different parts, according to the colour. The cornea itself does not receive light through its whole extent, for it is, generally, partly covered above and below by the open edges of the eye-lids.

Uses of the Cornea.

As the cornea is highly polished at its surface, the moment the light arrives there, a part of it is reflected, which contributes to give brilliancy to the eye. It is this which forms the images we observe on the cornea, which then performs the office of a convex mirror. The form of the cornea shews the effect it must have upon the light which enters into the eye; in consequence of its little degree of thickness, it causes the rays of light to converge a little toward the axis of the beam. In other words, it increases the intensity of the light which penetrates into the anterior chamber.

Uses of the Aqueous Humour.

In traversing the cornea, the rays of light have passed from a rarer into a denser medium, consequently they are drawn towards the perpendicular. If they passed out into the air, instead of entering the anterior chamber of the eye, they would be refracted from the perpendicular, which they had before approached, and, of course, would return to their first degree of divergence. But they enter into the aqueous humour of the eye, a denser medium than the atmosphere; and are, therefore, less refracted from the perpendicular, and of course diverge less, than if they had returned into the air.

Of all the light entering into the anterior chamber of the eye, that which passes through the pupil alone assists in performing the function of vision. All that falls upon the iris is reflected through the cornea, and enables us to distinguish the colour of the iris. The light does not undergo any new modification in passing through the posterior chamber of the eye, as the medium is still the same.

Uses of the Crystalline Humour.

It is in passing through the crystalline humour that light undergoes the modification which is most important in the function of vision. Philosophers compare the action of this body to that of a lens, the use of which is to collect together the rays of light upon a certain part of the retina. But as the crystalline humour is far from being a lens, we shall confine ourselves to simply announcing this commonly received opinion; observing at the same time, that the subject requires to be further investigated All that can be positively said on the subject is, that the crystalline humour must increase the intensity of the light which it directs to the bottom of the eye, in a much greater degree, from the circumstance of the posterior being more convex than the anterior surface. It may likewise be added, that the light which passes near the circumference of the crystalline humour. is probably refracted differently from that which passes through the centre.* Of consequence the dilatation or contraction of the pupil, must have an influence upon the mechanism of vision, which appears to deserve the attention of philosophers.

All the light that strikes on the anterior surface of the crystalline, does not pass into the vitreous humour, but is partly reflected. A part of this reflected light returns through the aqueous humour and cornea, and contributes to form the brilliant appearance of the eye; another part strikes upon the posterior surface of the iris, and is absorbed by the black matter which is found there. It is probable that some degree of reflection is produced by each of the laminæ forming this humour.

* The structure of the crystalline may have the effect to correct the aberration of sphericity which the common lens produces.

Uses of the Vitreous Humour.

The vitreous humour possesses a less degree of refracting power than the crystalline; of consequence the rays of light which, after having traversed the crystalline, penetrate into the vitreous humour, are drawn from the perpendicular at the point of contact. Its use, then, as respects the direction of the rays in the eye, is to increase their convergency. It may, perhaps, be said that nature might have arrived at the same result, by increasing the refractive power of the chrystalline humour. But the presence of the vitreous humour in the eye, has another and more important use; it is to allow a sufficient extent of expansion of the retina, and thus greatly to extend the field of vision.

What we have thus said of a beam of light passing from a point placed in a prolongation of the anterior-posterior axis of the eye, will apply with equal truth, to beams passing from every other point, towards the eye, with only this difference; that, in the first case, the rays tend to unite at the centre of the retina, while, in the other instance, they have a tendency to unite at some other point, according to the direction from which they proceed. Thus, those which pass from below, upwards, unite at the superior part of the retina, and those which come from above, unite at the inferior part of this membrane. The rays of light thus form, at the bottom of the eye, an exact representation of each of the objects which are placed before it, but with this difference, that the images will have a position the reverse of the objects they represent.

Different methods have been had recourse to, to establish this point. For a long time experiments were made with eyes artificially constructed. Glass was made to represent the transparent cornea, and crystalline humour, and water the aqueous and vitreous humour. Another mode was generally employed, before the publication of my memoir "On the images formed at the bottom of the eye." It consisted in placing in an aperture of the window shutter of a darkened room, the eye of some animal, as for example, that of an ox or sheep, having first carefully removed the posterior part of the sclerotica. There could then be seen, very distinctly, upon the retina, the images of objects placed in such a manner, as to transmit the rays through the pupil.

I had recourse to a much more convenient method for accomplishing this purpose. I took the eyes of rabbits, pigeons, small dogs, or ducks, in which the choroid and sclerotic coat are nearly transparent; I then removed, carefully the fat and muscles, and by directing the transparent cornea towards brilliant objects, I saw distinctly the images of those objects formed upon the retina. This process was known to Malpighi and Haller; the only circumstance peculiar to myself in this respect, consists in my having selected for this purpose white rabbits, white pigeons, and white mice; the eyes of albinos would probably be found equally good. These will be found much the most favourable to the success of this experiment. The sclerotic coat is thin and almost transparent; the choroid is equally thin, and as soon as the animal is dead, the blood which coloured it disappears, and ceases to offer any perceptible obstacle to the passage of the light.

The ease and distinctness with which we are thus enabled to perceive the images, suggested to me the idea of making some experiments, which might confirm or invalidate the commonly received theory of the mechanism of vision.

If we make a small opening in the transparent cornea, and allow a small portion of the aqueous humour to escape, the distinctness of the image becomes lost. The same thing takes place when we suffer a portion of the vitreous humour to escape, by a puncture through the sclerotica, which shews that the proportions of the aqueous and vitreous humours are such as to be necessary to perfect vision. I have likewise endeavoured to determine the laws of the dimensions of the image, relatively to the distance of the object; and I have found that the size of the image is perceptibly proportional to the distances. M. Biot had the politeness to confirm with me this result, which is likewise conformable to that given by Le Cat, in his "Treatise on Sensations." This author employed artificial eyes in his experiments.

I made a small opening at the circumference of the cornea, near its junction with the sclerotic coat, and evacuated all the aqueous humour through this aperture. On presenting the cornea towards a lighted candle, the image appeared to me, other things being equal, to occupy a much larger space than before. The image was evidently less distinct, and formed by a light much less intense than that of the same body, seen in the other eye of the same animal, that I had placed in a similar situation with respect to the candle, but which I had preserved whole, for the purpose of making the comparison. This experiment agrees with what we have before said of the use of the aqueous humour, in the mechanism of vision.

The same effect will be produced by removing the cornea. When this is done by a circular incision, made at the point where it unites with the sclerotic coat, the image will not appear to change its dimensions, but the light which forms it, loses very sensibly its intensity. We have before remarked, that the size of the opening of the pupil probably influences, to a considerable degree, the mechanism of vision. After having removed the cornea, it is easy to enlarge the pupil, by a circular incision made into the tissue of the iris; the image in this case becomes enlarged.

As the use of the crystalline humour is to increase the brilliancy and distinctness of the image, diminishing at the same time its size, we ought to expect that the absence of this body would produce a reverse effect. When we extract or depress this humour, by a process similar to the operation for cataract, the image is always formed at the bottom of the eye, but it is considerably increased in size. It becomes at least four times larger than that produced in the entire eye, under the same circumstances. The image is likewise very indefinite, and the light produced very weak. Take away from the same eye the aqueous and crystalline humours, and the transparent cornea, and leave nothing, of all the media of the eye, but the capsule of the crystalline lens, and the vitreous humour, and it will be found that there is no longer any image formed upon the retina. The light still passes very freely, but it no longer affects a particular form, in relation to that from which it emanates.

The greater part of these results agree very well with the theory of vision, generally admitted at the present day. There is, however, one point in which they differ essentially; this is respecting the distinctness of the image. From theory we are led to infer, in order that the image may be distinct, that it is necessary that the form of the eye should vary, or that the crystalline humour should be carried backwards or forwards, according to the distance of the object. These changes, which have been assumed actually to take place, have, by turns, been attributed to the compression of the globe of the eye by the recti and oblique muscles which move it, to the contraction of the crystalline humour, or to the action of the ciliary processes. Of late M. Jacobson has asserted, that this effect was produced by the aqueous humour, entering or passing out of the canal of Petit. Now experience contradicts this theory, and, of course, all these explanations fall to the ground.

It would be very incorrect, however, to assert that every thing took place in the eye of the living, precisely as it does in that of the dead animal. There is this essential difference, that, in the living animal, the pupil dilates or contracts, according to the intensity of the light, and, perhaps, according to the distances of objects. Observation shews, that, when the light is very brilliant, the pupil contracts almost to a point, so that the opening can be scarcely distinguished, which must have the effect to diminish the size of the image. On the contrary, when the light passing from any object is very inconsiderable, the pupil dilates very much, which must produce an enlargement of the image.

Motion of the Iris.

Some assert that the pupil varies its dimensions according to the distances of objects; but this point cannot be considered as satisfactorily ascertained. The only circumstance which can be considered as fully established, in the motion of the iris, is the influence exerted upon it by the intensity of the light.

The mechanism of the motions of the iris, has occupied much of the attention of physiologists. Some have supposed it was composed of muscular fibres, and have explained the motion of this membrane by the action of its fibres; others have considered it as being of a peculiar nature. Mery and Haller have referred its motion to erection. According to them, the motion of the iris is excited sympathetically by the action of the light upon the retina. Of late M. Maunoir, of Geneva, has distinguished in the iris two sorts of fibres; the one, which occupies the circumference of the iris, he calls *radiant;* the other irregularly concentric, forming the centre of the membrane, he calls the *pupillary muscle.* M. Maunoir asserts that these fibres are muscular, but brings no satisfactory proof to support this opinion.*

It is said that certain individuals have possessed the power of controling the motions of the iris by the will, and it is asserted by naturalists, that many birds, such as parroquets and night birds, present the same phenomenon.

A beam of light directed upon the iris does not cause any motion of it, which seems to shew, that the nerves of this part belong to the ganglionic system. A section of it, which is sometimes made in surgical operations, is not painful; but has sometimes been followed by vomiting. The irritation of the iris with the point of the needle, in the operation for cataracts, does not cause any sensible motion in this membrane, as I have ascertained from experience.

Messrs. Fowler and Rinhold, have found that the galvanic fluid, when directed upon the eye of man, and other animals, is followed by contractions of the iris. Dr. Nysten has likewise witnessed the same effect in the bodies of criminals, recently executed.—But must we therefore necessarily conclude with these authors that the movements of the iris must be the result of muscular motion? I think not. In these experiments the retina, as well as the iris, has been submitted to the influence of the galvanic fluid; and they do not prove therefore that the contraction of the iris was not the result of irritation upon the retina.

Uses of the Choroid Coat.

The principal use which this serves in vision, is absorbing the light, immediately after it has passed through the retina, by means of the black matter with which it is impregnated. The effects found to be produced by a varicose state of the vessels of

* It has been remarked that the pupil is very much enlarged in persons debilitated by excessive venery, and by those affected with engorgement of the abdominal viscera, hydrocephalus, intestinal worms, &c. A single application of certain narcotic plants upon the conjunctiva, particularly the *Belladonna,* dilates the pupil for several hours; it is likewise remarked that in cerebal affections, the pupil is either very much enlarged or very much contracted. The motions of the pupil are in general an index of the sensibility of the retina. Attention to the motions and state of the iris, is very useful in medicine.

this membrane, must be considered as a confirmation of this opinion. In those individuals who are affected by this disease, the dilated vessels remove the black matter with which it is covered, and every time that the image of the object falls upon that point of the retina which corresponds to these vessels, the object appears to be spotted red. The state of vision in certain white animals, and in albinos, where the choroid coat and iris are not coloured black, strongly sustains this assertion. In them vision is extremely imperfect during the day, so that they can scarcely see how to direct themselves.

M. Le Cat, and some others, have attributed to the choroid coat the faculty of perceiving light, but this opinion is completely destitute of proof.

Uses of the Ciliary Processes.

There have been no opinions advanced concerning the use of these parts, but what are extremely vague and unsatisfactory; they are generally believed to be contractile. Some suppose, that they are destined to move the iris, and others to move forward the chrystalline humour. M. Jacobson asserts that their use is to dilate the openings which, according to him, the canal of Petit presents anteriorly, for the purpose of allowing the aqueous humour to enter, or be discharged from this canal, which would have the effect to displace the crystalline lens. Some persons imagine that the ciliary processes are secretory organs, for the production of the black pigment found on the posterior surface of the iris and on the choroid coat, or even of a part of the aqueous humour. Mr. Edwards, in a memoir on the Anatomy of the Eye, asserts that they contribute chiefly to the secretion of the aqueous humour, an opinion before advanced by Dr. Young, secretary to the Royal Society of London, in the Philosophical Transactions. M. Ribes has promulgated a similar opinion, with this difference, "he supposes that the ciliary processes maintain life and motion in the crystalline and vitreous humours." But there are many animals which have no ciliary processes, in which the humours exist. Haller supposed that they preserved the crystalline humour in the most favourable situation. According to this anatomist, they adhere to the capsule of this humour, both at their points and posterior side, by means of the black matter with which they are covered.

Action of the Retina.

If we speak here singly of the action of the retina in vision, it is only to facilitate the study of this function. In reality no distinction exists between the action of this membrane, and that of the optic nerve, much less of the sensorium. The action of the retina is a vital action, and its mechanism is completely unknown. The retina receives the impression of light, when it exists within certain limits of intensity. A weak light makes no impression upon the retina, and a very strong light disables it from acting. When too brilliant a light strikes suddenly upon the retina, the effect produced is called *dazzling;* and the retina remains for some moments afterwards incapable of perceiving the presence of light. This effect is produced by looking steadily at the sun. When we have remained a long time in darkness, even a weak light dazzles us. If the light which falls upon the eye be extremely weak, and if we still endeavour to examine objects, the retina becomes very much fatigued, and we soon feel a sensation of pain in the orbit, and even in the head.

A light, the intensity of which is not very great, but which acts during a certain time on a fixed point of the retina, causes insensibility in that point. If we look, for some time, at a white spot upon a black surface, and if we then suddenly turn our eyes to a white surface, we seem to see a black spot. It is because the retina has become insensible at the point which had been fatigued by looking at the white spot. On the other hand, when the retina has been for a long time without acting, in some of its points, whilst the others have acted, the point which has remained in a state of repose, becomes possessed of a much greater degree of sensibility, which causes objects to appear as if they were spotted. We may explain in this manner how it happens, that, after having viewed a red spot for some time, white bodies appear spotted with green. In this case, the retina has become insensible to the action of the red ray, and it is well known, that when the red ray is taken from a beam of light, it produces the sensation of green. Similar phenomena occur when we look for some time on a red body, or those of any other colour, and then look suddenly upon white, or other coloured surfaces.

We are enabled to distinguish with great accuracy, the direction of the light which is received upon the retina. We believe instinctively that the light passes in a right line, and that this line is a prolongation of that pursued by the ray, which has entered the cornea. Whenever the light, before arriving at the eye, has been modified in its course, the impression produced upon the retina is inaccurate. This is a principal source of those illusions which often take place in vision, and which are therefore called *optical illusions.*

The retina may receive at the same time impressions over its whole extent, but then the sensations which result from them are very imperfect. It can only be strongly affected by the image of one or two objects, although a much greater number are painted there.

The centre of this membrane appears to enjoy a more exquisite sensibility than its other parts. It is on this part that we receive the image, when we wish to examine an object with attention.

Does light act by simple contact with the retina, or is its peculiar effect produced by traversing this membrane? The presence of the choroid, or rather of the black matter covering it, inclines us to the latter opinion. It has been said, that the place that corresponds to the centre of the optic nerve, is insensible to the impression of light. I do not know of any fact which directly proves this assertion. I much doubt whether the experiment of Mariote, which is generally spoken of in medical books, be correct; but if it were, I think it would be very wrong to conclude from this, that the retina is insensible at the point which corresponds to the centre of the optic nerve.

Action of the Optic Nerve.

There can be no doubt that the optic nerve transmits to the brain, instantaneously, the impressions made upon the retina by the light; but we are absolutely ignorant of the mode in which this is done. The manner in which the two optic nerves run together, near the sphenoid bone, without doubt, must have a great influence upon the transmission of impressions received by the eyes. But it is not easy to decide, among the various opinions which have been advanced on this point, which is best, as they all have some degree of probability.

Action of both Eyes.

Notwithstanding what has been said at different periods, and the efforts which have of late been made by M. Gall to prove that we only see with one eye at a time, it appears to me to be demonstrable, not only that both eyes concur at the same time in vision, but that it is absolutely necessary that they should act thus for the perfect performance of certain important acts of this function. There are, however, circumstances in which it is convenient to employ but one eye. For example, when we wish to judge correctly of the direction of light, to take aim with a gun, or to ascertain if bodies are on a level, or in a right line. There is another situation where it is convenient to employ but one eye; it is when the two organs are unequal, either in refractive power or sensibility. It is for the same reason that we shut one eye, when we look through a magnifying glass.

But, with the exception of these cases, it is much more effectual to use both eyes at the same time. The following experiment, of my own, appears to me to prove that both eyes see at the same time one object. Receive into a darkened chamber a beam of light upon a plain surface; then take glasses of sufficient thickness, each of which presents one of the prismatic colours, and place them in turn before the eyes. If the sight be good, and especially if both eyes possess equal power, the image will appear of a dirty white, whatever may be the colour of the glass you employ. But if one of the eyes be much stronger than the other; you will see the image of the same colour as the glass. These results have been confirmed in the presence of M. Tillaye, junior, in the cabinet of physic, of the Faculty of Medicine. The same object then produces two impressions, while the brain perceives but one: but for this purpose it is necessary that the motions of the eyes should be in harmony. If, in consequence of disease, the regular motions of the eyes be interrupted, we then receive two impressions instead of one; and this it is which constitute *strabismus*. We may likewise voluntarily receive two impressions instead of one; we have only to interrupt the harmony in the motion of the eyes to produce this effect.

On estimating the distance of Objects.

Vision is essentially produced by the contact of light with the retina, though we are constantly in the habit of referring the cause of the sensation to the bodies from which the light passes, notwithstanding they are at a great distance. It is plain that this must be the effect of an intellectual process.

Our judgment of the distances of bodies is very materially affected by the *distance*. We judge with accuracy when they are near us; but it is not so when they are very remotely situated; then our judgment is often erroneous; but, when objects are at a very great distance, we are constantly in error.

The united action of both eyes is absolutely necessary to judge exactly of the distances of objects, as may be proved by the following experiment. From a thread suspend a ring, then fix to a rod, a hook, which will readily enter the ring. Place yourself at a convenient distance, and endeavour to introduce the hook. If you use both eyes, you will readily succeed at each attempt; but if you shut one eye, and then endeavour to hook the ring, you will fail. The hook will either go beyond, or fall short of the ring, and it will only be, by accident, and after many fruitless attempts, that the hook will be introduced. Persons whose eyes possess unequal power, will not succeed in this experiment, even when they use both eyes.

When a person loses one eye by accident, it often happens that they will not be able to judge accurately of distances for more than a year. I once saw a remarkable case of this kind, where the person, for several months afterwards, had to make several attempts before he could seize those objects which were placed, even very near to him. Generally speaking, persons who have but one eye judge very inaccurately of distances. The size of objects, the intensity of the light which passes from them, the presence of intermediate objects, &c. influence very much the accuracy of our judgment with respect to the distances of objects. Our judgment is much more exact when the objects are placed, on the same plane with ourselves. Thus when we look from a high tower upon objects situated below, they appear to us much smaller than when they are viewed, at the same distance, on the same plane with ourselves. The same observation applies to objects placed far above us; and from this we see the necessity of giving a considerable volume to those objects which we place in elevated situations, for the purpose of being seen at a distance. The smaller the object, the more necessary it is that it should be placed near to the eye, to be seen distinctly. That which may be called *the point of distinct vision*, therefore, varies very much. We see a horse distinctly at thirty feet distance, but we do not see a bird distinctly at the same distance. If we wish to examine a hair, or feather of these animals, they must be brought very near to the eye. At the same time, the same objects may be seen with equal distinctness at different distances. For example, it is indifferent to many persons whether they place a book, when reading, at the distance of one or two feet from the eye. The intensity of light thrown upon an object, influences, very materially, the distance at which the object may be seen distinctly.

On estimating the size of Bodies.

The correctness of our judgment, respecting the size of bodies, depends more upon sagacity and habit, than upon the particular action of the apparatus of vision. We form our judgment of the dimensions of bodies, from the size of the image formed at the bottom of the eye, the intensity of the light which passes from the object, the distance at which we suppose it to be placed, and especially from our habit of seeing similar objects. This is the reason why our judgment of the size of bodies that we see for the first time, is so faulty, when we do not know the distance. A mountain, seen at a distance for the first time, appears to us generally much smaller than it really is, because we think it to be much nearer than it actually is. Beyond a very inconsiderable distance, we fall into an illusion which the judgment cannot overcome. That objects at a distance appear infinitely smaller than they actually are, is sufficiently evident from the appearance of the celestial bodies.

On estimating the motion of Bodies.

We judge of the motion of bodies, by that of the image upon the retina and by the variations in the size of this image; or, what amounts to the same thing, by the change in the direction of the light which arrives at the eye.

In order that we may follow the motion of a body, it is necessary that the image should not be displaced too rapidly, for then we cannot perceive it. This is the case with projectiles thrown by fire arms, when they pass very near us; but when they move at a distance, if they be of considerable size, as they are exposed for a much longer time to the eye, the field of vision being greater, we can then distinguish them. To judge correctly of the motion of bodies it is necessary that we should ourselves be at rest.

We distinguish, with difficulty, the motion of the bodies which are at a distance, especially if they leave or approach us. Indeed in this case we can only form our judgment of the motion of the body, by the variation in the size of its image. Now this variation being infinitely small, when the body is at a distance, it is extremely difficult, and often absolutely impossible, to appreciate it.

Generally, we distinguish with great difficulty, and often we cannot perceive at all, the motion of bodies which are displaced very slowly. This may arise from the real slowness of the motion, as in the case of the hand of a watch, or it may arise from the slowness with which the image moves over the retina, as that of the stars and very distant objects.

Optical Illusions.

From what has been said of the manner that we judge of the distance, size, and motion of objects, it is easy to perceive that we are exposed to numerous errors. These errors are distinguished in science by the name of *optical illusions.* We judge, for the most part, with sufficient accuracy of those objects which are placed near to us, but are frequently deceived with respect to those which are at a distance. The illusions into which we fall, with respect to neighbouring objects, arise either from the reflection, or refraction which the light undergoes, before arriving at the eye, and to that law which we instinctively establish in our own mind, namely, that the light passes from the object to the eye in a straight line. It is to this cause that we must refer the illusions occasioned by mirrors. We see the object behind the mirror, in a prolongation of the line that the ray describes, in directly approaching the eye. To this cause must be referred the apparent increase or diminution of volume of bodies, seen through glass. If the rays are made to converge, the body will appear to us larger; if to diverge, it will appear smaller. The use of these glasses produces another illusion. The objects appear surrounded by the different colours of the solar spectrum, because the surfaces of glass not being parallel, decompose the rays of light in the manner of a prism.

Distant objects are constantly producing illusions, which we cannot prevent, because they necessarily result from certain laws that govern the animal economy. An object appears so much the nearer to us, as its image occupies a more considerable space upon the retina, or as the light passing from it is more intense. Of two objects, of different volume, equally brilliant, and placed at equal distances, the largest will appear the nearest; unless there be some accidental circumstance that enables us to judge more correctly If two objects of equal volume, be placed at equal distances from the eye, but are unequally bright, the most brilliant will appear the nearest. It would be the same, if the objects were at unequal distances. This any person may convince themselves of by observing a row of reflectors; if the light of one be more intense than the rest, it will appear to be the first of the row, while that which is really first, will appear last, if it be less bright. An object which is so placed as not to have any thing between our eye and it, will appear nearer than when this is not the case; the reason of which is, that intermediate objects enable us to compare distances, and thus to form a more exact judgment.

When our eye is struck by a bright object, while those surrounding it are enveloped in darkness, it appears much nearer, than it is in reality. Every one must have noticed this effect of a light at night. Objects appear small according to their distances; thus the trees in a long avenue appear to us to grow smaller and approach each other, when they are at a considerable distance. It is by attending to these various sources of illusions, and the laws of the animal economy in which they are founded, that artists are enabled to produce them at pleasure. The painter, for example, in many cases, does nothing more than transfer to his canvass those optical illusions into which we are constantly falling. The construction of optical instru-struments is also founded on these principles. Some augment the intensity of the light coming from objects; others, by rendering it divergent, or convergent, increase or diminish the apparent volume of objects, &c. &c.

There are some optical illusions which we are able to remove by experience and the exercise of the other senses. The following extremely curious history of a blind man restored to sight, related by the celebrated Cheselden, is strikingly illustrative of this:—

"When he first saw, he was so far from making any judgment of distances, that he thought all objects whatever touched his eyes, as he expressed it, as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was, in any object, that was pleasing to him: he knew not the shape of any thing, nor any one thing from another, however different in shape or magnitude: but, upon being told what things were, whose forms he before knew by feeling, he would carefully observe, that he might know them again; but, having too many objects to learn at once, he forgot many of them; and, as he said, at first he learned to know, and then forgot, a thousand things in a day. One particular only, though it may appear trifling, I will relate: having often forgotten which was the cat, and which the dog, he was ashamed to ask; but catching the cat, which he knew by feeling, he was observed to look at her steadfastly, and, then setting her down, said, so puss, I shall know you another time. He was very much surprised, that those things which he had liked best, did not appear most agreeable to his eyes, expecting those persons would appear most beautiful whom he loved most, and such things to be most agreeable to his sight that were so to his taste We thought he soon knew what pictures represented, when showed to him, but we found afterwards that we were mistaken; for about two months after he was couched, he discovered that they represented solid bodies, when, to that time, he considered them as party-coloured planes, or surfaces diversified with variety of paint, but even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts, which by their light and shadow appeared now round and uneven, felt only flat like the rest, and asked, which was the lying sense, feeling or seeing? Being shewn his father's picture, in a locket in his mother's watch, and told what it was, he acknowledged a likeness, but was vastly surprised; asking, how it could be, that a large face could be expressed in so little room; saying, it should have seemed as impossible to him, as to put a bushel of any thing into a pint. At first he could bear but very little light, and the things he saw he thought extremely large; but, upon seeing things larger, those first seen he conceived less; never being able to imagine any lines beyond the bounds he saw; the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look any bigger.

"When couched of his other eye, he says, that objects at first appeared large to this eye, but not so large as they at first appeared to the other; and looking upon the same object with both eyes, he thought it looked about twice as large as with the first couched eye only, but not double."*

This case does not stand alone, but others very similar to it have been witnessed by other surgeons; the results have been nearly the same in all. We may draw the following inferences from these facts; viz. that the exact judgment which we become capable of forming of the distances, magnitudes, and forms of bodies, is the result of experience, or, what amounts to the same thing, of the education of the sense of vision. This will be confirmed by considering vision at different periods of life.

Vision at different Periods of Life.

The eyes are the first parts formed in the fœtus. In the embryo, they appear like two black spots; at seven months, they become capable of modifying the light, so as to form an image upon the retina, as we know by experiment; until that period they cannot do this, because the pupil is closed by the *membrana pupillaris.*† At seven months this membrane disappears. The

* I have preferred an abstract of this case in the language of the author, to a translation.—*Trans.*

† According to M. Edwards, the membrana pupillaris is formed by a prolongation of the membrane of the aqueous humour, and by the external lamina of the

common mode of expressing this, is saying, that it is ruptured; it is probably absorbed. At this period, the fœtus likewise becomes capable of living independently of the mother, it sometimes happens, however, that no trace of this membrane is found in the eyes of the fœtus at six, or even five months.

There are some points in which the eyes of the fœtus and those of adults differ; they are not, however, very remarkable. In the first, the sclerotic coat is thinner, and even slightly transparent; the choroid is reddish externally, and the black pigment less thick internally; the retina is proportionally more developed, and the aqueous humour is more abundant, which causes the cornea to project; finally, the crystalline humour is much less dense than in the adult. Before birth, the eye-lids are closed tightly together, as if they were glued; in some animals they are even united by the conjunctiva of the eye-lids, which passes from the one to the other, and is not ruptured until after the birth.

As we advance in life, the quantity of the humours of the eye insensibly diminish, until the adult age. After this, they diminish in a manner much more perceptible; this becomes very palpable in advanced age. The crystalline humour, especially, not only becomes more dense, but it begins to lose its transparency, and to assume a yellow colour, which at last becomes quite deep. At the same time that the crystalline becomes yellow, it becomes much more dense, and contracts a slight opacity that may increase with age, until it becomes completely opaque.

We learn from experiment, that the eye of the new born infant then, is very well adapted to act upon the light, and to form images upon the retina. During the first month of its life, however, the infant gives no evidence of its being sensible to the light. Its eyes move slowly, and in a doubtful manner. It is not

choroid coat. According to this anatomist, there is no aqueous humour in the anterior chamber of the eye, before the rupture of this membrane, but this humour is accumulated in the posterior chamber, which proves, 1st, that the membrane of the aqueous humour is not the secretory organ of this fluid; 2d, that this organ exists in the posterior chamber; 3d, that before the seventh month, the membrane of the aqueous humour presents all the characters of a serous membrane; particularly that of forming a sac without an opening.

until the seventh week that it exhibits strong proofs of its sensibility in this respect. Even then it is only attracted by a very brilliant light. It seems pleased to look upon the sun, at first, but soon it becomes sensible merely to the light of day. In the mean time, however, it seems indifferent to other objects; the first which it notices are generally of a red, or some other brilliant colour. At the end of some days, its attention is arrested by bodies of different colours, but it is a long time before it becomes capable of forming any idea of the distance, or size of bodies. It extends its hands to seize even the most remote objects; and, as the first of its wants is food, it endeavours to carry to its mouth every thing it gets hold of, whatever may be its nature, or dimensions. It appears, therefore, that vision is extremely imperfect during this early period of life; but, from exercise, and especially from experience, resulting from continual mistakes, the sight becomes perfected by a sort of education.

It has been asserted that children see objects double and reversed; this assertion, however, is entirely unsupported by any proof. It has been said also, but without any more reason, that the refracting parts of the eye being more abundant, they see objects much smaller than they actually are. Vision soon acquires all the perfection of which it is susceptible, and in general it undergoes no modification until the approach of old age. It is then that the changes, which we have pointed out in the humours, tend to render it more distinct; but, what principally contributes to this effect, is the diminished sensibility of the retina.

Three causes affect vision in old age, viz. 1st, the diminution of the quantity of the humours of the eye, a circumstance that diminishes the refractive powers of the organ, and prevents the individual from distinguishing accurately neighbouring objects. He is obliged, in order to examine them, either to hold them at a distance, so that the light which penetrates into the eye is less divergent, or to employ convex glasses, which diminish the divergence of the rays; 2nd, commencing opacity of the crystalline humour, which weakens the vision, and, increasing, tends to cause blindness, by producing the disease, generally known by the name of *cataract;* 3d, the diminished sensibility of the retina, or if you choose, of the brain, which renders obtuse the perception of impressions, produced upon the eye, and often terminates in complete and incurable blindness.

OF HEARING.

Hearing is the function by which we are made acquainted with the vibratory motions of bodies. *Sound* is to hearing, what light is to vision. Sound is the result of an impression produced upon the ear, by the vibratory motion impressed on the particles of bodies by percussion, or any other cause. This word describes also the vibratory motion itself. When the particles of a body have been thus put in motion, they communicate it to the elastic bodies which surround them; these act again in the same manner, and thus the vibratory motion is propagated, oftentimes to a considerable distance. Elastic bodies alone, generally speaking, are capable of producing and propagating sound. For the most part, solid bodies produce it, while the air is often the vehicle which transmits it to our ear.

We may consider it according to its *intensity*, *note*, and *tone*.

The *intensity* of sound depends on the extent of its vibrations.

The *note* depends on the number of vibrations in a given time, and is divided into *sharp* and *grave*. A *grave note* arises from few vibrations; in a *sharp note* they are very numerous. The most grave note, that the ear can perceive, is formed by thirty-two vibrations in a second: the most sharp, by twelve thousand. Between these two extremes, are included all appreciable sounds; that is, all sounds of which the ear, instinctively, perceives the vibrations. *Noise* differs from an *appreciable sound* in this, that the ear cannot distinguish the number of vibrations of which it is formed.

An appreciable sound, which is composed of double the number of vibrations of another sound, is called its *octave*. Between these two, are seven intermediate sounds, called the *diatonic scale*, or *gammut;* they are distinguished in France by the names *ut*, *rè*, *mi*, *fas*, *sol*, *la*, *si*.

When we put in motion a sonorous body, by percussion, we hear at first one distinct note, more or less intense, or more or less sharp, as the case may be. This is the *fundamental note*. With a little attention, one perceives, that it produces at the same time other sounds, these are called *harmonics;* this will be readily observed by striking the cord of an instrument.

The *tone* depends on the nature of the sonorous body.

Sound is propagated by all elastic bodies. The velocity with which it moves, varies, according to the body that serves to propagate it; it moves through air at the rate of a thousand and forty-two feet in a second; its transmission is still more rapid through water, stone, and wood, &c.* It generally loses its force in passing, in a proportion which is directly as the squares of the distances. This, however, is only in passing through air; sometimes its intensity is increased in passing; this is the case when it traverses very elastic bodies, as certain metals, wood, condensed air, &c. Sharp, grave, intense, and weak notes are propagated with equal rapidity and without being confounded. It has been generally supposed that sound is propagated in a right line, forming cones analogous to those of light, with this essential difference, that cones of sound have only an oscillatory motion, while those of light are progressive. When sound meets with a body that opposes it, it becomes reflected in the same manner as light, that is, the angle of incidence is equal to the angle of reflection. The form of the body which reflects sound has a similar influence. The slowness with which sound is propagated, produces certain phenomena, the reason of which may be easily explained, such for example as echo, the mysterious chamber, whispering gallery, &c.

Apparatus of Hearing.

This organ is very complicated, but we shall not enter into minute anatomical details, for at present we know but little of the uses of the different parts that constitute this sense.

As in the apparatus of vision, so in that of hearing, we find a collection of organs, which concur in their physical properties, and behind them a nerve destined to receive, and transmit impressions. The apparatus of hearing is composed of the external, middle and internal ear, and auditory nerve.

External Ear.—We shall comprehend under this denomination, the external cartilage, and the *meatus auditorius externus.*

* Vide Memoirs d'Arcueil, vol. ii.

External Cartilage.—The size of the external cartilage is different in different individuals. The external face, which in a well formed ear projects a little forward, presents on its anterior surface, five eminences, called the helix, ante-helix, tragus, ante-tragus, and the lobule. There are likewise three cavities, viz. that of the helix, the scapha, and the concha. This cartilage is very elastic, the skin which covers it is thin and dry, and is attached to the cartilage by a strong cellular tissue, which contains but little adipose substance but the lobule contains a large quantity. Beneath the skin is seen a large number of sebaceous follicles, which furnish a white and shining matter, which gives to the skin its polish, and, perhaps, a part of its flexibility. There is likewise seen on the different prominences a few muscular fibres, to which some have given the names of muscles, but which are really mere *vestiges.** This part receives many nerves and blood vessels, is very sensible, and easily becomes red. It is attached to the head by ligaments of cellular tissue, and muscles called, according to their positions, anterior, superior, and posterior. These muscles are very much developed in many animals, but, in man, they can only be considered as *vestiges.*

Meatus auditorius externus.—This part extends from the concha to the membrana tympani, its length varying according to the age; in the adult, it is from ten to twelve lines. It is narrowest at its middle part, and is slightly curved upwards and forwards. At its external orifice, it is furnished with hairs, like the entrance to the other cavities. It is composed of bone, and a fibro-cartilage, which is confounded with the external cartilage, and a fibrous part which completes it above; the *skin* with which it is covered is thin, and is expanded over the external surface of the *membrana tympani.* Beneath this skin, there are a great number of sebaceous glands which secrete the *cerumen,* or wax, a yellow, bitter, and unctuous substance, the uses of which will hereafter be pointed out.

Middle Ear.—The middle, comprehends the cavity of the tym-

* The name *vestiges* is given by the French anatomists to those parts of animals which are without any perceptible use; but which seem only intended to indicate the uniform plan that nature has pursued in the construction of animals.

panum, the small bones contained in it, the mastoid cells, and the eustachian tube, &c.

The *tympanum* is the cavity which separates the external from the internal ear. Its form is that of a portion of a cylinder, somewhat irregular. Its internal wall presents above an oval hole, called the *foramen ovale*, which communicates with the vestibule, and is closed by a membrane; immediately below, is a small projection, and beneath this a cleft, in which is lodged a nervous filament; still lower there is a round opening called the *foramen rotundum*, which corresponds to the external *scala* of the *cochlea*, and is also covered by a membrane. The external opening of the tympanum is covered by a membrane, called the *membrana tympani*. This membrane passes obliquely downwards and inwards, it is tense, very thin, and transparent; it is covered externally by an expansion of the skin, and internally by a mucous membrane, which lines the tympanum; it is also covered on this side by a nerve, called the *cord of the tympanum*; its centre gives attachment to the handle of the *malleus*; its circumference is attached to the osseous extremity of the *meatus auditorious externus*, and it adheres firmly at every point, affording no opening by which the external, and middle parts of the ear can communicate with each other. Its texture is dry, fragile, and has nothing analogous to it in the animal economy; there cannot be distinguished about it either fibres, or blood vessels, or nerves.

The circumference of the tympanum presents anteriorly; 1st. The eustachian tube, by which the tympanum communicates with the superior part of the pharynx. 2d. The opening by which the tendon of the internal muscle of the *malleus* enters. Posteriorly is seen—1st. The opening into the mastoid cells, which are irregular cavities always filled with air, opening into the thickest part of the mastoid process. 2d. The pyramid, a small hollow projection which gives attachment to the muscle of the *stapes*. 3d. The opening by which the *cord of the tympanum* enters into this cavity. Below there is a small cleft called "*gleniodale*," by which the tendon of the anterior muscle of the malleus enters; and the cord of the tympanum passes out to anastomose with the lingual nerves of the fifth pair. Above there is nothing but small openings through which blood vessels

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pass. The tympanum, and all the openings with which it abounds, are covered by a very delicate mucous membrane. This cavity is always filled with air, and contains four small bones, viz: the *malleus*, the *incus*, the *os orbiculare*, and the *stapes*, which are so connected together as to form a chain, extending from the *membrana tympani*, to the *foramen ovale*, where the base of the *stapes* is fixed. There are small muscles, destined to move this chain, and to stretch and relax the membranes to which it is attached. Thus the internal muscle of the malleus draws it anteriorly, moves the whole chain of small bones, and stretches the membranes. The anterior muscle produces an opposite effect. We may suppose also that the small muscle lodged in the pyramid, and which is attached to the neck of the stapes may produce a slight tension upon the chain, drawing it towards itself.

Internal Ear or Labyrinth.—This is composed of the cochlea, the semicircular canals, and the vestibule.

The Cochlea is a bony canal, of a spiral form, which receives its name from its supposed resemblance to the shell of a snail. This is divided into two cavities, the *scalæ of the cochlea*, which are distinguished into internal, and external, and are separated by a thin partition, partly osseous and partly membranous. The external scala communicates with the tympanum, through the foramen rotundum; the internal terminates in the vestibule.

Semicircular Canals.—There are three cylindrical canals of a semicircular form, of which two are arranged horizontally, and the third vertically; these canals terminate in the vestibule. They contain bodies of a greyish colour, which enlarge towards their extremities.

Vestibule.—This is the central cavity, or point, where the other parts meet. It communicates with the tympanum through the *foramen ovale*, or as it is sometimes called the *fenestra ovalis*, with the internal scala of the cochlea, with the semicircular canals, and with the *meatus auditorious internus*, by a great number of small openings. All these cavities of the internal ear are contained in a very hard bone, from this circumstance called the *os petrosum*. They are covered with an extremely delicate membrane, and are filled with a thin limpid fluid, called the fluid of Cotunnus, which passes through two small apertures, called the aqueducts of the cochlea, and vestibule; they likewise contain the auditory nerve.

Auditory Nerve.—This nerve arises from the fourth ventricle of the brain; it enters into the labyrinth by foramina at the bottom of the *meatus auditorious internus.* Having arrived at the vestibule, it is divided into several branches, of which one remains in the vestibule, another enters the cochlea, and two are distributed through the semicircular canals. The manner in which these different branches are arranged in the cavities of the internal ear has been described, with great care, by Scarpa. It would not be proper to enter here into a more minute detail.

In terminating this very concise description of these parts, it will be proper to remark, that the internal and middle ear are traversed by several nervous filaments, which probably have some influence in the function of hearing. For example, the facial nerve passes through a canal hollowed out from the os petrosum. In this canal it receives a filament of the vidian nerve, and it supplies the cord of the tympanum, which is spread over this membrane. Two other anastomoses are likewise seen in the ear; to one of which the attention of anatomists has been called by Mr. Ribes, the other has been recently discovered by M. Jacobson.

Mechanism of Hearing.

Use of the external Cartilage of the Ear.—It collects together the sonorous rays, and directs them towards the meatus auditorius externus; this it more effectually does, from its size and elasticity, and from its being detached from the head, and directed forwards. Boerhave pretended to have proved, by an elaborate calculation, that all the sonorous rays which fall upon the external surface of the cartilage, are necessarily conducted towards the auditory opening. This assertion is, however, evidently incorrect, at least in some individuals, because, in some instances, the antehelix is more prominent than the helix. As all the rays are to be directed toward the concha, what will become of those that fall on the posterior part of the antehelix in these cases? This cartilage, however, is not absolutely necessary to the function of hearing; for in man, and some animals, it may be removed, without the hearing being impaired, for more than a few days.

Uses of the Meatus auditorious externus.—This transmits sound to the membrana tympani, like any other tube, partly by its walls, and partly by the air contained in it. The hairs which are placed at its entrance, and the cerumen, prevent the introduction of foreign bodies, such for example as grains of sand, dust, or insects, &c.

Uses of the Membrana tympani.—This membrane receives the sound transmitted to it through the auditory opening. Under what circumstances this membrane is rendered tense, by the action of the internal muscle of the malleus, or relaxed, by the contraction of the anterior muscle of this small bone, we are, at present, entirely ignorant; conjectures only have been heretofore formed on this subject. An opening made into this membrane does not, very essentially, impair the hearing.* As it is dry and elastic, it is peculiarly adapted to the transmission of sound to the air contained within the tympanum, and to the chain of small bones. The cord of the tympanum will necessarily participate in the vibrations, and transmit to the brain certain impressions. The contact of a foreign body with this membrane is exceedingly painful, a violent noise also occasions severe pain in this part. The membrane of the tympanum may be torn, or even entirely destroyed, without the hearing being essentially impaired.

Uses of the cavity of the Tympanum.—Its principal use is to transmit to the internal, the sounds which it has received from the external part of the ear. This transmission of sound by the tympanum takes place; first, by the chain of small bones, which acts particularly on the membrane of the foramen ovale;† second, by the air which fills it, and which acts upon the whole of the os petrosum, but especially upon the membrane of the foramen rotundum; third, by the vibration of its walls.

* For the various opinions which have been formed concerning this membrane, see the works of Haller, vol. 5.

† We are ignorant of the use of those motions which are produced by the chain of small bones. The loss of these bones, except the stapes, does not, necessarily, occasion deafness; we have remarked, however, that those individuals who are in this situation, only preserve this sense for two or three years.

Uses of the Eustachian Tube.—This serves to admit the external air, so that the pressure on both sides of the membrana tympani being equal, of course, no obstacle is offered to the vibrations of the membrane, by which sound is transmitted to the internal parts of the ear. The obliteration of this tube is a frequent cause of deafness. It has been supposed that this tube assists in conducting the sound to the internal parts of the ear, but this is a mistake, there being nothing to support the assertion. It allows the air to escape from the tympanum, when the atmosphere has been violently agitated by a loud noise, and afterwards admits it to this part, and to the mastoid cells. The air in the tympanum, being very much rarified from the heat of the body, diminishes the intensity of the sound which it transmits.

Uses of the Mastoid Cells.—This is a point which is not well ascertained. It is supposed that they assist in augmenting the intensity of the sound which arrives at the tympanum. If they produce this effect, it must be rather by the vibration of the laminæ which separate the cells, than by that of the air which they contain. Sound may reach the tympanum otherwise than by the *meatus auditorious externus.* The sounds which strike upon the bones of the head, may be directed towards the temporal bone, and the percussion thus arrive at the ear. We all know how distinctly the noise arising from the machinery of a watch is perceived by placing it in contact with the teeth.

Uses of the Internal Ear.

We are but little acquainted with the functions of the internal ear. We suppose that the sonorous vibrations are propagated in various ways, but, principally, by the membrane of the fenestra ovalis, that of the foramen rotundum, and by the internal parietes of the tympanum, and that the fluid contained within the cavities of the internal part of the ear, sometimes called the fluid of Cotunnus, must receive vibrations, which it transmits to the auditory nerve. We may likewise suppose that this fluid performs the extremely important function, of breaking the impulse of very intense vibrations, which would otherwise essentially injure the auditory nerve. It is probable that, in this case, the fluid flows back into the aqueducts of the cochlea, and vestibule, which, according to this view, have considerable analogy in their functions with the eustachian tube.

The external scala of the cochlea, must receive vibrations, principally, by the membrane of the foramen rotundum; the vestibule, by the extremity of the chain of small bones; the semicircular canals, by the walls of the tympanum, and, perhaps, by the mastoid cells, which are often prolonged beyond these canals. We are, however, absolutely ignorant of the precise share, which each of the internal parts of the ear take in performing the function of hearing.—The osseo-membranous partition which separates the two scalæ of the cochlea has given rise to an hypothesis which no one believes at the present day.

Action of the Auditory Nerve.

This nerve receives impressions and transmits them to the brain, which perceives them with a greater or less degree of exactness in different individuals. Many persons are said to have a false ear, that is, they are incapable of accurately distinguishing sounds. We cannot explain the action of the auditory nerve, nor that of the brain in hearing, but many observations have been made on this function.

A sound, to be distinctly perceived, must range within certain limits; if it be too violent, it gives us pain, if too weak, it causes no sensation. We may perceive a great number of sounds at a time. Appreciable sounds combined, and succeeding each other in a certain manner, are a source of agreeable sensations. There is one art, the object of which is to arrange sounds in such a manner as to produce this effect; this art is *music*. Certain combinations of sounds, on the contrary, cause disagreeable sensations. Very sharp sounds wound the ear, and those that are very intense and grave, lacerate the membrana tympani. The absence of the fluid of Cotunnus from the cavities of the internal ear destroys hearing. When a sound has been long continued, we often think that we continue to hear it, even after it has ceased.

Action of both Ears.

We receive two impressions from sound, but only perceive one. It has been said that we never use but one ear at a time, but this is incorrect. It is true, that when sound arrives directly at one ear, it is received with more facility by that, and more imperfectly by the other, and, in this case, we only use one ear. When we wish to listen attentively to sounds, which we fear to lose, we place ourselves in a situation that the sonorous rays may enter directly into the concha of one ear; but, when we wish to determine from what point sound proceeds, and in what direction it comes, we are obliged to use both ears, because it is only in comparing the intensity of the two impressions, that we are able to distinguish the place from which the sound comes. If, for example, we stop one ear, and another person makes a slight noise at some distance, it will be impossible for us to determine the direction of the sound, though we should succeed every time with both ears. Sight greatly assists us in judging of sounds, for in profound darkness, even with both ears, it is often impossible to decide from what point a noise comes.

Sound also enables us to judge of the distance by which we are separated from bodies which produce it. But, in order that our judgment may be correct in this case, it is necessary that we should be familiar with such sounds, otherwise our judgment will be always erroneous. In this case, our judgment is formed on the following principle, viz. that a very intense sound comes from a neighbouring body, and a very weak sound from a distant body. If it should happen that the intense sound comes from a distant body, and the weak sound from a near one, we then fall into an error of hearing. Generally, we are easily deceived in judging of the distance from which sound proceeds; here too vision and reason materially assist our judgment.

The different degrees of convergence or divergence in the sonorous rays, do not appear to influence hearing, nor do we modify the direction of the sonorous rays, but to make a greater number enter into the ear. This is the effect produced by hearing trumpets which are used by the deaf. It is sometimes necessary to diminish the intensity of sounds; in this case we place a soft inelastic substance in the meatus auditorius externus.

Modification of hearing by Age.

The ear is formed very early in the fœtus. At birth, the internal ear and small bones, are nearly the same as at any period of life, but the parts which belong to the middle and external ear are not in a condition to act, which constitutes an essential difference between the eye and ear. The external cartilage is comparatively very small, and soft, of course possesses but little elasticity, and is, therefore, but imperfectly prepared to perform the function, to which it is destined. The parietes of the external passage are in a similar state, the membrana tympani is very oblique, forming, in some measure, the upper part of the canal, and is therefore badly arranged to receive the sonorous rays. All the external part of the ear is covered with a soft whitish matter, which obstructs its functions. The cavity of the tympanum is also proportionally small, and, instead of air, contains a thick mucus. The mastoid cells do not exist. But, as age advances, the auditory apparatus acquires that arrangement and perfection, which we have described in the adult. In old age, the changes that take place in the physical structure of the ear, are so far from being unfavourable, as happens in the eye, that they appear, on the contrary, to improve it. All the parts become harder and more elastic; the mastoid cells extend themselves through the *os petrosum*, and surround, on all sides, the cavities of the internal ear.

The loudest noises have no sensible effect upon new born infants, but, after some time, they seem to distinguish sharp sounds; these are the sort of sounds generally made use of by nurses to attract their attention. It is a long time before an infant judges correctly of the intensity or direction of sounds, and, especially, before he attaches any meaning to articulate sounds. As he prefers the most vivid light, so in the same manner he is pleased, for a long time, with sounds that are loud and sharp. But, although the physical structure of the auditory apparatus becomes more perfect in old age, it is nevertheless certain, that the hearing becomes more imperfect, even at its first approach, and that there are very few old men who are not more or less deaf. This appears to arise from a diminution of the humour of Cotunnus, and a progressive loss of sensibility in the auditory nerve.

SENSE OF SMELLING.

There are many bodies in nature, which suffer particles of extreme tenuity to escape from them, which diffuse themselves in the atmosphere, and are carried, by this vehicle, to a great distance. These particles constitute *odours.* One of the senses is destined to recognise and appreciate these particles, and thus an important connexion is established between animals and them. Those bodies, the particles of which are fixed, are called *inodorous.*

There is a great difference among odorous bodies, in the manner in which they develope their odours. Some do not suffer them to escape, except when they are heated, others when they are rubbed; some exhale weak odours, others only those which are strong. Such is the tenuity of these odorous particles, that a body may exhale them for a long time, without altering, sensibly, its weight.

Every odorous body has a peculiar odour. As these bodies are very numerous, it has been attempted to class them, but all these attempts have heretofore proved fruitless. We can only distinguish odours into weak and strong, agreeable and disagreeable. We speak, however, of a musk-like odour, aromatic, and fetid odours, &c. They are, likewise, sometimes distinguished into fugitive, and tenacious. For the most part, however, we can only designate them by comparing them with that of some known body.

Nutritious, medicinal, and even poisonous qualities have been attributed to odours; but, in such cases, these opinions seem to have been formed by confounding the influence of odours, with the effects of absorption. A man who pounds jalap for some time, will be purged, as if he had taken its substance into his stomach. This effect cannot be properly referred to the effect of odour, but to the fine particles of the jalap which are floating in the air, and which are thus introduced into the circulation, either with the saliva, or the air which he respires. It is to the same cause to which we must attribute the intoxication of persons exposed, for some time, to the fumes of spirituous liquors. The air is the vehicle by which odours are, generally, transported to a distance, but they are also produced in a vacuum. There are some bodies which dart forth their odoriferous particles with a considerable degree of force; but this subject has not received the attention which it deserves. It has not been fully ascertained, if odours observe, in their progress, any thing analogous to the convergence and divergence, reflection and refraction of luminous rays. Odours attach themselves to, or combine with, many fluids, as well as many solid bodies; a method which is often taken to preserve them for a long time. Liquids, vapours, gases, and many solid bodies, when reduced to an impalpable, or even coarse powder, have likewise the property of acting upon the organs of smell.

Apparatus of Smelling.

The olfactory apparatus may be compared to a sort of sieve, placed in a spot over which the current of air, that is introduced into the chest in respiration, passes, and which is destined to detain all the foreign bodies, which may happen to be mixed with the air, particularly odours.

This apparatus is extremely simple. It differs essentially from that of vision or hearing in this, that we do not find before the nerve, any parts which are placed there to modify the physical effects of the excitant, the nerve being, in a great measure, naked. The apparatus is composed of the pituitary membrane, which covers the nasal cavities, of the membrane which lines the sinuses, and of the olfactory nerve.

The Pituitary Membrane.—This covers the whole extent of the nasal fossæ, increases very much the thickness of its cornets and is prolonged beyond their edges and extremities, in such a manner, that the air cannot traverse the nasal fossæ, except by very narrow and lengthened passages. This membrane is thick, and adheres tenaciously to the bones and cartilages to which it is attached. Its surface presents an infinite number of small projections, which are considered, by some, as nervous papillæ, but have been supposed by others to be mucous cryptæ; they are, however, very vascular. These projections give to the membrane a velvet-like appearance. The pituitary membrane is smooth and soft to the touch, and receives a great number of blood-vessels and nerves.

The passages which the air passes through, to arrive at the back part of the mouth, deserve attention. They are three in number, and are divided by anatomists into inferior, middle, and superior passages. The inferior is by far the largest, longest, and least oblique and tortuous; the middle is narrower, nearly as long, and deeper from above, downwards; the superior is much the shortest, and most oblique, and narrowest. It is also proper to add to these passages, the very narrow interval which separates the septum of the nostrils, through its whole extent, from the external walls. Such is the extreme narrowness of all these canals, that the least swelling of the pituitary membrane renders the passage of the air through the nasal fossæ difficult, and, sometimes, impossible. The two superior canals communicate with cavities, which are considerably spacious, hollowed out of the bones of the head, and are called sinuses. They are the maxillary, palatine, frontal, and sphenoidal sinuses. Those which are found in the thick part of the ethmoid bone, are sometimes distinguished by the name of *cellulæ ethmoidales.*

These sinuses do not communicate with any others than the two superior canals. The frontal and maxillary sinuses, and the anterior cells of the ethmoid bone open into the middle passage; the sphenoidal, and palatine sinuses, and the posterior cells of the ethmoid bone open into the superior canal. These sinuses are covered with a thin, soft, and apparently mucous membrane, loosely attached to their walls; it secretes, in greater or less abundance, a substance called nasal mucus, which is continually spread over the surface of the pituitary membrane, and appears to be useful in smelling. A considerable extent of these sinuses is always found where this sense exists in great perfection. This is, at least, one of the most positive results of comparative physiology.

The Olfactory Nerve.—This arises by three distinct roots from the posterior, inferior, and internal part of the anterior lobe of the brain. In passing towards the cribiform plate of the ethmoid bone, it is of a triangular shape; here it becomes suddenly enlarged, and is then divided into a great number of small filaments which are ramified over the pituitary membrane, principally, at the superior part of this membrane.

It is important to remark, that the filaments of the olfactory nerve have never been traced on the inferior cornet, or spongy bone, on the internal face of the middle, nor any of the sinuses. The pituitary membrane not only receives the nerves of the first pair, but receives also a great number of filaments arising from the internal face of the spheno-palatine ganglion; these filaments are distributed over the inferior parts of the membrane. It is supplied also by the ethmoidal filament of the nasal nerve, and receives from it a large number of small filaments. The membrane which covers the sinuses receives also some small nervous branches.

The nasal fossæ communicate externally through the nostrils, the form, magnitude, and direction of which vary in different individuals. The interior of the anterior nares is garnished with hairs, and their dimensions are increased and diminished by the action of certain muscles. The nasal fossæ open into the pharynx by the posterior nares.

Mechanism of Smelling.

The sense of smell is exerted at the moment that the air traverses the nasal fossæ in its passage to the lungs. It is very rare that we can perceive any odour in the air, at the moment it escapes from these organs, though this is sometimes observed, especially, in certain organic affections of the lungs.

The mechanism of smell is extremely simple; it is only necessary that the odoriferous particles should be stopped, by the pituitary membrane, especially in those narrow passages where it receives the filaments of the olfactory nerve. As it is precisely at the superior part of the nasal fossæ, where the passages are the narrowest, that they are the most covered with mucus, it is probable that this is also a spot where a great portion of the odoriferous particles are stopped. It is easy to understand the use of this mucus; its physical properties appear to be such, that it has a much greater affinity for the odoriferous particles, than for the air. It, therefore, separates them from this fluid, and retains them upon the pituitary membrane, where they produce the sense of smell. It is very important, in the exercise of this function, that the nasal mucus should preserve the same physical properties; every time they are changed, as happens in the different stages of coryza, the sense of smell is either lost or essentially impaired.*

From what has been said of the distribution of the olfactory nerves, it is evident, that odours, when they come to the superior part of the nasal cavities, will be more easily and vividly perceived. It is for this purpose that we modify inspiration, so that the air shall be directed upon this point, when we wish to perceive vividly, or accurately the odour of a body. It is for the same reason, that those who take snuff endeavour to place this substance towards the upper part of the nasal fossæ. It would seem that the internal surfaces of the cornets are extremely well arranged to stop the odour, at the moment that the air passes through; and, as their sensibility is very great, we are induced to believe that they assist in the function of smelling, although the filaments of the first pair of nerves have never been traced upon them.

Physiologists are not agreed as to the precise use of the nose in smelling; it appears intended to direct the air, charged with the odorous particles, towards the superior part of the nasal fossæ. Persons whose noses are deformed, especially flattened, and those who have small nostrils directed forward, have, generally, the sense of smell very imperfectly. The loss of the nose, by disease or by accident, causes nearly an entire loss of this sense. According to the interesting remarks of M. Beclard, we may restore the use of this part, in individuals who are in this situation, by fitting an artificial nose.

It has been supposed that the use of the sinuses, for the most part, consists in supplying the nasal mucus. But there are other uses which may be attributed to them, viz. to serve as a depot of the air charged with the odorous effluvia, and to increase the surface to which it may be applied. But all these opinions must be considered doubtful. Vapours, and gases appear to act in the manner of odours, on the pituitary membrane; the mode, however, is, probably, somewhat different. Bodies reduced to a coarse powder, have also a powerful action on this membrane;

* This is the explanation given in the School of Medicine in Paris. It seems at first satisfactory, but, on a nearer examination, it will be found to rest on many assumed facts—e. g. the affinity of the nasal mucus for odours, the deposition of the odorous particles on the pituitary membrane, &c.

their first contact is even painful, but habit changes this pain into pleasure, as we see in snuff-takers. In the practice of medicine, we have often recourse to this property of the pituitary membrane, of producing instantaneously an acute pain, by the application of certain pungent odours.

In speaking of the sense of smelling, it is not proper to be silent concerning the hairs which garnish the nostrils;—they are, perhaps, intended to prevent the foreign bodies, which float in the air, from entering the nassal fossæ. Their functions are very analogous to those of the eye-lashes, and of the hairs found at the entrance of the external passage of the ear.

It has been generally admitted, that the olfactory nerve is especially destined to transmit to the brain, impressions made by odorous bodies; but there is nothing which proves, positively, that the other nerves, which are expanded upon the pituitary membrane, do not concur in this function.

Modification of Smell by Age.

The olfactory apparatus is but imperfectly developed at birth. The nasal cavities, and the different cornets, scarcely exist; and the frontal sinuses cannot be distinguished, though there is reason to think that infants are capable of exercising this function. I think I have seen children, soon after birth, exert this sense upon the aliments which were presented to them. With the progress of age, the nasal cavities develope themselves, the sinuses become formed, and, in this respect, the olfactory apparatus continues to grow more perfect, until old age. The sense of smell remains until the last moments of life, excepting in those cases where there is some organic affection of the part, such, for example, as some change in the secretion of the mucus, &c. which frequently takes place.

The sense of smell is designed to make us acquainted with certain properties of bodies, especially of the class of substances called aliments. For the most part, those substances, the odour of which is disagreeable, are not useful as aliments, but are frequently dangerous. Many animals appear to have the sense of smell much more perfectly than ourselves. This sense is also a source of many agreeable sensations, which have a marked influence upon the condition and feelings of the individual.

ON THE SENSE OF TASTE.

TASTE is the impression made upon the tongue by certain bodies; those substances which produce this effect are called *sapid.* It has been supposed that the degree of sapidity in any body might be judged of by its solubility. But there are some bodies which are insoluble, yet have a strong taste, and there are others which are very soluble that have scarcely any perceptible taste. Sapidity appears to have some relation to the chemical nature of bodies, and to the general effects which they produce on the animal economy.

Tastes are very various, and numerous; several attempts have been made to divide them into classes, but this has never yet been done with complete success; at the same time we have been rather more fortunate in this respect, than with odours. This undoubtedly arises from the fact, that the impressions which we derive from the sense of taste, are less transient than those of smell. The propriety of the following distinctions among sapid bodies is universally acknowledged, viz, *acrid, acid, bitter, sweet, rough, &c.* There is another division of these bodies which will be admitted by every one, because it is founded upon organization; it is that of *agreeable* and *disagreeable.* Animals instinctively establish this distinction. This division is also the more important, because those bodies, the taste of which is agreeable, are usually those that are most nutritious; and, on the contrary, those, the taste of which is disagreeable, are often injurious.

Apparatus of Taste.

The tongue is the principal organ of taste; at the same time the lips, the internal surface of the cheeks, the palate, the teeth, the pharynx, the œsophagus, and the stomach itself, are susceptible of impressions from the contact of sapid bodies. The salivary glands, the excretory ducts of which open into the mouth, and those follicles which pour out mucus into this cavity, concur powerfully in the function of taste. Independently of the mucous follicles found on the superior surface of the tongue, which have received the name of *fungous papillæ,* there are found still smaller projections, the most numerous of which are called *villous papillæ,* and still others, less numerous, which are disposed on the side of the tongue, in two ranges, and are called *conical papillæ.*

All the nerves distributed on those parts which are destined to receive the impression of sapid bodies, must be comprised in the *apparatus of taste.* Thus the inferior maxillary, and many branches of the superior maxillary nerves, among which it is proper to mention the filaments which arise, from the *spheno-palatine ganglion,* particularly the *naso-palatine nerve* of Scarpa, the nerve of the ninth pair, the glosso-pharyngeal nerve, &c. all appear to assist in the function of taste.

The lingual nerve of the fifth pair is usually considered by anatomists as the principal nerve of taste; for its filaments, they assert, may be traced to the villous and conical papillæ of the tongue. I have myself attempted to do this but in vain. Notwithstanding I have employed the most delicate instruments, magnifying glasses, and microscopes completed according to the principles of Mr. Woolaston, all my efforts have been unsuccessful. We entirely lose sight of them, the moment we arrive at the exterior membrane of the tongue. We do not succeed better with the other nerves which are distributed over this organ.

Mechanism of Taste.

In order that we may exercise the function of taste perfectly, it is necessary that the mucous membrane which covers these organs should be in a state of integrity, that it should be covered with mucus, and that the saliva should be poured out abundantly. When this membrane is dry, the taste is very imperfect. It is likewise necessary that these fluids should be in a natural state, for if the mucus be thick, and yellowish, or if the saliva be acid or bitter, &c. the taste will be defective,

Some authors assert that the papillæ of the tongue are in a complete state of erection, during the action of tasting; I believe however, that this assertion is entirely destitute of foundation.

It is sufficient that the body be in contact with the organs of taste, in order that we may judge correctly respecting it; but, if it be a solid body, it will be often necessary, that it should be first dissolved in the saliva, but this is not necessary in liquid or gasseous bodies.

It would seem that sapid bodies produce a certain chemical action upon the epidermis of the mucous membrane of the mouth; this is at least the case in some instances; e. g. vinegar, mineral acids, alkalis, a great number of salts, &c. In these cases the colour becomes changed, sometimes it is white, sometimes yellow, &c. They produce analogous effects upon the dead body. It is probable that the manner in which this combination takes place, has some relation to the promptitude with which sapid bodies act, and the duration of the impression.

No satisfactory explanation has yet been given why the teeth are strongly influenced by certain sapid bodies. It appears from the researches of M. Miel, a distinguished dentist of Paris, that this is the effect of imbibition. The experiments of this gentleman prove, that the teeth imbibe, promptly, the fluids with which they are in contact.

The different parts of the mouth appear to have each a peculiar susceptibility to the action of sapid bodies; for some more particularly affect the tongue, some the teeth, and others the gums. There is another class of these bodies, the action of which seems to be, almost exclusively, confined to the palate and pharynx.

There are some bodies which leave, for a long time, their taste in the mouth; this is especially the case with aromatic substances. This *remaining taste* is sometimes perceived over all the mouth, and sometimes occupies only one spot. Acrid bodies, for example, leave their impression in the pharynx, acids on the lips and teeth; peppermint leaves an impression which exists at the same time in the mouth and pharynx.

It is necessary that bodies should remain for some time in the mouth, in order that their taste may be appreciated. When they pass rapidly through this cavity, the impression which they make is almost nothing; this is the reason why we swallow quickly those substances, the taste of which is disagreeable, and why, on the contrary, we allow those things to remain long in the mouth, the taste of which is pleasant.

When we taste a substance, the flavour of which is strong and permanent, vinegar for example, we become insensible to the action of less pungent bodies. We often make use of this observation to enable our patients to avoid the disagreeable taste of certain medicines.

We are capable of perceiving many tastes, at the same time, and of distinguishing their different degrees of intensity.

By this means we are sometimes enabled to distinguish, very exactly, the chemical nature of different substances. The taste, however, never arrives at this degree of perfection, but by long experience, or, if you choose, by a complete education.

I know not any fact which proves, that the lingual nerve is exclusively the nerve of taste. The experiment mentioned by M. Richerand, does not appear to me to decide this question; this seems also to be the opinion of this learned professor.

Modification of Taste by Age.

It is difficult to say, if taste exists in the fœtus; it is certain, however, that the principal organ, and the nerves which are sent to it, are fully developed. That this sense exists at the time of birth, there can be no doubt, as any person may satisfy themselves, by rubbing upon the tongue, or even upon the lips, any bitter or sweet substance. The impressions of taste appear to be very vivid in children, as is shown by their repugnance to every thing, the flavour of which is strong.

Taste remains in the most advanced age, though it is true, that it becomes weaker, and that old persons, generally, prefer aliments and drinks, the flavour of which is strong. But this is one of the peculiarities of their organization, which requires very active excitants for the maintainance of its powers, when they have become very weak.

Taste assists us in the choice of aliments; together with smell, it enables us to distinguish those substances, which are injurious, from those which are useful; it is likewise the sense which enables us to form the most correct judgment of the chemical composition of bodies.

OF TOUCH.

Touch is the sense which makes us acquainted with the greatest number of the properties of bodies. In consequence of its being less subject to error than the other senses, and because, in certain cases, it enables us to detect it, it has been considered as the most perfect of the senses. But it will be seen, that its advantages have been very much overrated, both by physiologists and metaphysicians.

We must distinguish between *feeling* and *touch*. Feeling is, with few exceptions, common to every part of the body, especially the cutaneous and mucous surfaces; it exists in all animals, while touch is evidently confined to parts particularly destined to this purpose. Touch does not exist in all animals, but it is nothing more than feeling, united with muscular contraction, and directed by the will. In a word, in the act of feeling, we may be considered as being passive, but in exercising the sense of touch, we are active.

Of the Physical Properties of Bodies which are the objects of the Sense of Touch.

This sense enables us to become acquainted with nearly all the physical properties of bodies. The form, dimensions, different degrees of consistence, weight, motion and vibration of bodies, are all circumstances of which we are enabled to judge, with accuracy, by the sense of touch.

The parts destined to this sense, do not alone perform this function. In this respect, it differs very essentially from the other senses. As in the greater number of instances, however, it is the skin which receives the impressions of touch from those bodies which surround us, it is necessary to say something concerning its structure.

The Skin.—This forms the envelope of the body; it is lost in the mucous membranes, at the entrance of all the cavities, but it is incorrect to say, that these membranes are a continuation of it.

Dermis.—The skin is principally formed by the *dermis*, the texture of which is fibrous, and is of different degrees of thickness, according to the parts which it covers. It adheres to these parts, sometimes by cellular membrane, and sometimes by a fibrous attachment. The *dermis* is nearly always separated from the subjacent parts by a lamina, which assists in the exercise of the sense of touch.

Epidermis.—The external surface of the dermis is covered by a solid substance secreted by the skin, called the *epidermis*.

The epidermis ought not to be considered as a membrane; it is a lamina of homogeneous substance, adhering by its internal surface to the dermis. It is pierced by an infinite number of small holes, some of which allow the hairs to pass through, and others the cutaneous transpiration to escape, and, at the same time, they assist in the absorption which is carried on by the skin. These are called the *pores of the skin*. It is proper to remark, with respect to the epidermis, that it is insensible, that it does not possess any of the properties of life, and that it is not subject to putrefaction. It is constantly taken away and again replaced, and its thickness is increased or diminished, according as the situation of the parts may require. It cannot be acted upon through the medium of the digestive organs.

Rete mucosum, or the mucous substance of Malpighi.—The connexion between the dermis and epidermis is intimate, nevertheless, we cannot doubt that there is between these two parts a particular lamina, in which important phenomena take place. The organization of this lamina is still but little known. Malpighi supposed that it was formed by a particular mucus, the existence of which has been long admitted, and which has been called the *rete mucosum*, or mucous substance of Malpighi. Others have considered it, with more reason, as a network of blood vessels.* M. Gall compares it to the cineritious substance found in many parts of the brain.

M. Guatier, in examining with attention the external surface of the dermis, observed small reddish projections, arranged in pairs. They are easily recognized when the dermis is denuded by the action of a vesicatory. These small bodies are regularly arranged in the palm of the hand and the sole of the foot. They are sensible, and are reproduced when they have been torn away. They appear, chiefly, made up of blood vessels. These bodies have been, for a long time, called *cutaneous papillæ*, but they have never been studied with care. The epidermis is pierced over their top by a small opening, by which we can observe drops of sweat to escape, when the skin is exposed to a temperature a

* In those cases where vesicatories have been applied to the part sometime before death, very numerous vessels, very small and filled with blood, may be distinguished on the external surface of the dermis.

little elevated. The skin contains a great number of sebaceous follicles; it receives many blood vessels, and a great number of nerves, particularly at those points which are destined to exercise the function of touch. We are entirely ignorant of the manner in which the nerves terminate in the skin; all that has been said of the nervous cutaneous papillæ, is completely hypothetical.

The functions of feeling and touch are assisted by the thinness of the dermis, a temperature of the atmosphere somewhat elevated, abundant cutaneous transpiration, as well as a certain thinness and flexibility of the epidermis. When the reverse of these circumstances exist, the sensibility and the touch are always more or less imperfect.

Mechanism of Feeling.

The mechanism of feeling is extremely simple; it is sufficient for the bodies to be in contact with the skin to enable us to form an idea, more or less exact, of their sensible properties. We are enabled to judge particularly of temperature by feeling. When bodies abstract caloric from us, we say they are cold, and when they impart heat, we say they are warm; thus, according to the quantity of caloric of which they deprive us, or which they impart to us, we determine their different degrees of temperature. The judgment which we form of temperature, is nevertheless far from being accurate, in relation to the quantity of caloric which our bodies give off or receive; we unconsciously institute a comparison between the temperature of the surrounding atmosphere, and those substances which are in contact with our bodies. If an object be colder than our body, but warmer than the atmosphere, it will appear warm to us, although it abstracts caloric when we touch it. This is the reason why such places as caves and wells, the temperature of which is uniform, appear to us cold in summer, and warm in winter. The capacity of bodies for caloric, influences also our judgment of temperature; for example, how different are the sensations caused by iron and wood, at the same temperature.

A body sufficiently warm to decompose chemically our organs, produces the sensation of burning. A body, the temperature of which is sufficiently low to absorb, very rapidly, a great proportion of the caloric of a part, produces a similar sensation; this any one may satisfy themselves of, by touching congealed mercury.

Those bodies which have a chemical action upon the epidermis, which dissolve it, such as the caustic alkali, and concentrated acids, produce impressions peculiar to these bodies, which may serve to distinguish them.

All parts of the skin are not endued with the same degree of sensibility; so that a body applied successively on different parts of the skin, will cause a series of very different impressions. The mucous membranes possess a very delicate sensibility. It seems hardly necessary to point out the great sensibility of the lips, tongue, conjunctiva, pituitary membrane, and the mucous membrane of the trachea, ureters, vagina, &c. &c. The first contact of those bodies, which are not naturally destined to come in contact with these membranes, is painful, though this effect ceases by habit.

Mechanism of Touch.

In man, the hand is the principal organ of touch; all the circumstances which are the most favourable to it are there found united. The epidermis is thin, polished, and very flexible, the cutaneous transpiration is abundant, and there is likewise an oily secretion. The vascular net-work, called the retè mucosum, is there in an unusual quantity, and the dermis is of very inconsiderable thickness; it receives many blood vessels and nerves; it adheres to the subjacent aponeurosis, by a fibrous attachment, and is sustained by an adipose substance and cellular membrane, which is very elastic. It is at the extremity, or *ball* of the finger, that all these arrangements exist in the highest degree of perfection. The motions of the hand are easy and various, so, in a word, that this part may be applied to every body, whatever may be the irregularity of its figure. While the hand remains immoveable upon the surface of a body, it only performs the function of feeling; it is necessary, in exercising the sense of touch, that it should move over the surfaces of bodies, in order to make us acquainted with their form, dimensions, &c. or to compress them, so that we may form just ideas of their elasticity, density, &c. When the dimensions of a body are very great, we employ the whole hand to examine it, if on the contrary the body is very small, we only touch it with the extremity of our finger. This organ is much more perfect in man than in brutes; his touch is so delicate, that it has been considered as the principal source of his intelligence.

From the highest antiquity, this sense has been considered more perfect than the rest, and has been described as the cause of human reason. This idea is maintained at the present day, and it has even been very much extended in the writings of Condillac, Buffon, and the modern physiologists. Buffon, in particular has attached such a degree of importance to touch, that he seems to have thought that the different degrees in which this sense was cultivated, was the principal cause of the difference observed in the minds of men; he enjoins, therefore, the importance of allowing infants the free use of their hands.

The touch, however, has really no superiority over the other senses; and if, in some cases, it assists us in seeing or hearing, in others, these senses afford it equal assistance; nor is there any reason to believe that the impression which it excites in the brain are more vivid than those which arise from the action of the other senses.

Modifications of Feeling and Touch by Age.

It is probable that the fœtus does not exercise this sense, at least in its more rigorous acceptation. It may be said that the first contact of the air with the skin of the new born infant causes severe pain, which is the reason of its cries. I believe, however, that this idea is unfounded.

Feeling and touch grow more obtuse with the progress of age. In old age they are sensibly diminished; at this period, the skin undergoes changes which are unfavourable to this sense. The epidermis is no longer soft and flexible, the cutaneous transpiration is not abundant, the fat which before sustained the skin is absorbed, and it becomes flaccid and rugous. We can easily imagine that all these causes will impair the functions of feeling and touch, especially when we recollect, that the power of receiving impressions, generally, becomes perceptibly diminished in old age.

By the exercise of this sense it may be brought to a very great degree of perfection, as is observed in many professions. A delicate touch is indispensable, both in a physician and surgeon.

Of Internal Sensations.

All the organs, like the skin, possess the faculty of transmitting to the brain impressions, when they are brought in contact with foreign bodies, or when they are compressed or bruised. They may be said, generally, to possess feeling. We must except, however, from this remark, the bones, tendons, aponeuroses and ligaments, which, in a state of health, are totally insensible, and may be even cut, burned, or torn, without the brain being affected by it. This important fact was not known by the ancients; they considered all the white parts of the body as nervous, and attributed to them properties which, we now know, only pertain to the nerves. It is to the experiments of Haller, and his disciples, that we are indebted for this useful information, which has exerted a powerful influence upon the progress of modern surgery.

Without the intervention of any external cause, all the organs may spontaneously transmit a great number of different impressions to the brain. They are of three kinds.

The first arises when there is a necessity that the organs should act; these may be called *instinctive desires.* Such are hunger, thirst, a desire to pass urine, respiration, and the venereal appetite.

The second takes place during the action of the organs; they are often obscure, but sometimes very vivid. Of this number are the impressions which accompany the different excretions, the impressions which we perceive during the period of digestion; thought itself may be included among this sort of impressions.

The third kind of internal sensations takes place when the organs have acted. To these kind belong the sensation of fatigue, varying, of course, according to the part affected.

It is necessary to add to these three kinds of impressions, those which arise from disease; these are very numerous, and a profound acquaintance with them, is indispensable to the physician. All these sensations which arise from within, independently of the action of external bodies, have been designated as *internal sensations.* Their consideration was neglected by the metaphysicians of the last century, but their study has of late engaged the attention of many distinguished authors, particularly of Cabanis, and M. Destutt Tracy; their history constitutes one of the most curious parts of ideology.

Of a supposed sixth Sense.

Buffon, in speaking of the intensity of those agreeable sensations which are produced by the approach of the sexes, has observed, in figurative language, that they depended on a sixth sense. The professors of animal magnetism, especially those of Germany, talk much of a sense which remains awake when the rest are asleep; that it is, particularly, developed in those persons who are called somnambulists; and that it gives to them the power of predicting future events. This sense, it is pretended, forms that instinct of animals, by which they become acquainted with dangers which are near. It resides in the bones, viscera, ganglions, and the nervous plexus.—To attempt to answer such reveries, would be only to throw away one's time.

M. Jacobson having discovered in the *os incisivum* of animals, a particular organ, suspected that it might be the source of a distinct order of sensations; but he has given no proof of this.

The faculty which bats have of directing their flight in the darkest places, has induced Spalanzani, and M. Jurine of Geneva, to think that these animals are possessed of a sixth sense; but M. Cuvier has shewn that this power of conducting themselves in the dark, is attributable to the sense of touch. There is, therefore, no evidence of a sixth sense.

OF SENSATIONS IN GENERAL.*

Sensations form the first part of the life of relation, they establish our *passive relations* with surrounding bodies. This expression *passive*, as any one will easily perceive, is true only in a limited sense; for sensations, as well as the other functions of the economy, are the result of the action of the organs, and, of consequence, are essentially *active*. Every substance which exists,

* These general sensations being founded on our knowledge of particular facts, we shall introduce them after having explained these facts. This course is conformable to the manner in which our ideas are formed.

is capable of acting upon our senses; we cannot know positively of their existence, but in this way. Sometimes they act directly upon our organs; at others, through the medium of other bodies, as light, odours, &c.

The greater number of bodies act upon several of our senses; others, again, only affect one. The organs of sensation are formed of an exterior part, which exhibits physical properties in common with other bodies, and of nerves, which receive impressions and transmit them to the brain. The exterior parts of the apparatus of vision and hearing are very complicated; those of the others are very simple. But in all, the relation between their physical properties, and other bodies is such that the least alteration in these properties, causes a marked derangement of function.

Nerves.

The nerves, which form the second part of the instruments of sensations, are the *essential organs of sense.* All the nerves have two extremities; the one is confounded with the substance of the brain, the other variously arranged in the organs. Each of these extremities have in turn been called the origin, and termination of the nerves. Some say, that all the nerves arise in the brain, and terminate in the organs; others, that they arise in the organs, and, by uniting, form the brain. These modes of expression are both improper, and convey very false ideas. They can be only useful in the description of the organs; but, as other expressions may easily be substituted, without at all obscuring the subject, it is desirable that they should be abandoned. It is evident enough, that the brain is not formed by the union of the nerves, and it is equally certain that the nerves do not arise from the brain. By these expressions we merely mean to describe, metaphorically, the disposition of the two extremities of each nerve.

Cerebral extremity of the nerves.—The cerebral extremity of the nerves are composed of very fine, and loose filaments, which are continued into the substance of the brain, for a short distance from the point where they are first perceived; these filaments, when united, form the nerve.

There is a marked difference between the nerves. Some are rounded, others flattened, others hollowed out at their sides, a great number are very long, and others very short. It may be asserted that, in form, colour, &c. there are no two nerves which exactly resemble each other. In general, they are so placed as not to be exposed to injuries from external causes. In going to the different parts, the nerves divide into large, and, afterwards, into smaller branches; and they terminate by filaments, so small, in the substance of the organs, that they cannot be distinguished, even by the assistance of the most powerful optical instruments. The nerves communicate among themselves, they anastomose, and thus form what is called a *plexus*.

Organic extremity.—With the exception of the optic nerve, the *organic extremity* of which can be easily distinguished, and of the auditory nerve, of which we have tolerably correct notions, we are absolutely ignorant of the disposition of the extremities of the nervous filaments in the tissue of the organs. We hear much of the *nervous extremities*, *papillæ*, *&c.* Physiologists are still in the habit of using these expressions; but all that is said on this subject is purely imaginary. It is easy to demonstrate that those bodies, which have been, and are still, called *nervous papillæ*, do not exist.

The nerves are, in general, formed of filaments, excessively delicate, which are probably reducible into still finer filaments, if our means of division were more perfect. These filaments, which have been called nervous fibres, communicate frequently with each other, and affect, in the body of the nerve, an arrangement similar to what is found in a plexus. It is generally supposed that a fibre is formed by an envelope, and a central pulp, similar in its nature to cerebral substance, but I believe that this is merely hypothetical. I have done all in my power to repeat the preparations, advised by anatomists to display this structure, but, with all my efforts, I have never been able to distinguish it. The tenuity of the nervous fibres, alone, appears to me to be a most powerful objection to it. Since, with the aid of a microscope, we can scarcely perceive the fibre itself, and may reasonably suppose, that this is formed by fibres, still more delicate; how, I would inquire, is it possible to distinguish a cavity filled with pulp?

Whatever may be the disposition of the substance, which forms the parenchyma of the nervous fibres, it is certain that it possesses the same chemical properties as the cerebral substance, and that each nerve receives very numerous small branches of arteries, in proportion to its volume, and a proportionate number of small veins.

The posterior branches of all those nerves which arise from the spinal marrow present, not far from the point where they unite with the anterior branch, an enlargement which is called a *ganglion.* These bodies are of a colour, consistence, and structure essentially different from those of the nerves, and their use is unknown. The nerve of the eighth pair, where it passes out from the cranium, exhibits enlargements of this kind.

Of the Mechanism, or Physiological Explanations of Sensations.

The physiological explanation of sensations consists, in the more or less exact application of the laws of physics, and chemistry, to the physical properties of that part of the organ, which is placed before the nerves, as has been remarked, in the particular history of each sensation. The moment we arrive at the uses of the nerves in these functions, no further explanation can be given. It is necessary to adhere rigorously to *facts.*

This consequence, so easy to deduce, does not seem to have been perceived, but by a very small number of authors; and, even in their works it is expressed very vaguely. All have endeavoured to explain the action of the nerves. The ancients considered these organs as the conductors of the animal spirits. At the period when physiology was governed by mechanical ideas, the nerves were supposed to be vibratory chords, although their physical condition is such as to prevent their vibration.

Some very intelligent men have supposed, that the nerves were conductors, and even the secretory organs of a subtle fluid, which they have called *nervous.* According to them, sensations are transmitted to the brain, by means of this fluid. At this moment, when the attention is directed towards the imponderable fluids, this opinion has attracted numerous disciples. I am acquainted with men who confer honour on the age, by their genius and learning, who are inclined to admit, that electricity exerts a considerable influence on the sensations, and other functions.* To pretend to explain the sensations, by referring them to certain vital properties, which are called *animal*, *perceptive*, *relative*, &c. is to have recourse to a most vicious mode of explanation; it is only a new way of expressing the difficulty, it by no means solves it. We shall, therefore, class the action of the nerves among the *vital actions*, which, as has been seen at the commencement of this work, are not susceptible of explanation, in the present state of science. But that the nerves are the agents for the transmission of those impressions, which are received from the senses, is conclusively demonstrated by observation and experience.

Thus, if a man receive a wound, which affects a nervous trunk, the part to which the nerve is distributed becomes insensible. If the optic nerve be the one which has suffered, the individual will become blind, and if the auditory, deaf. We may produce these effects at any time upon brutes, by dividing, or even simply by compressing the nerves. When the compression is removed, the nerve is restored to its sensibility as before. In man, as in brutes, the wounding of a nerve produces severe pain. In a word, all those diseases which alter, even slightly, the tissue of the nerves, have a manifest influence upon their action, as agents of transmission.

We are completely ignorant of the utility of the numerous anastomoses which are observed among the nerves. The suppositions which have been made to explain their use, are sufficient to show that physiology is still in its infancy.

Sensations are either vivid or weak. The first time a body acts upon our senses, the impression produced is generally vivid. The vivacity of the impression diminishes, if the action of the body be frequently repeated, and, at last, it is scarcely perceived. This fact is expressed, when we say, that *habit blunts our feelings*. The existence of man, being as it were, measured out by

* This seems by no means improbable, from the experiments of Dr. Wilson Philip. He repeatedly found that when two animals, under similar circumstances, were allowed to eat equal quantities of food, and the eighth pair of nerves were divided; if one was submitted to the influence of the galvanic fluid, and the other not, the food underwent the process of chymification in the first, while it remained entirely unchanged in the last. This experiment wa amply confirmed.—*Trans.*

the vivacity of his sensations, he is induced to seek, continually, for new impressions, which are always the most vivid; hence his inconstancy, inquietude, and ennui, if he remain long exposed to the same causes of sensation.

We possess the power of rendering our sensations more vivid and distinct. In order to do this, we dispose the organ of sense in the most favourable manner, we receive but a small number of sensations at a time, and we direct all our attention to them; thus arises the important difference between seeing, and examining, hearing and listening, the common exercise of the sense of smell, and snuffing, &c. Nature has also given us the power of diminishing our sensations. Thus we draw down the eyebrows, and close the eye-lids, when the impression produced by the light is too vivid, we breathe through the mouth, when we wish to diminish the effect of a strong odour, &c.

The different sensations also direct, assist, modify, and may even mislead each other. Smell seems to be the sentinel and guide to taste, and taste in its turn exerts a powerful influence over smell. Smell may exercise its functions separately from those of taste, but the reverse cannot be always done; as the aliments and drinks cannot pass into the mouth without acting, more or less, upon the nose; whenever their taste is very disagreeable, their odour soon becomes so; again, those aliments, the odour of which is most unpleasant, soon lose this quality when the taste very vehemently desires them.*

We know, from numerous observations, that the vivacity of the impressions received by the senses, is increased by the loss of one of these organs. For example, the smell is more delicate in blind or deaf persons, than in those who enjoy all their senses. I think, however, that the absence of smell, which we often meet with, does not give any increased activity to the other senses.

Sensations are *agreeable or disagreeable;* the first, when they are vivid, constitute *pleasure*, and the second *pain*. By pleasure and pain nature induces us to concur in the order which she has established among organized beings.

Though it may appear like sophistry to say, that pain is but the shadow of pleasure, still it is certain, that persons who have

* Cabanis.

exhausted all the sources of pleasure, and have thus become insensible to all ordinary sensations, have recourse to the causes of pain, and gratify themselves by their effects. Do we not see, in all large cities, that men who are debauched and degraded, find agreeable sensations, where others experience nothing but the most intolerable pain?

It is necessary to remark, that those sensations which come from the senses, are distinct. All our ideas, and the knowledge we have of nature, are thus received. Internal sensations, or sentiments, do not possess these characters. In general, they are confused, and often vague, we are not conscious of them; they are not engraved upon the memory, but are always more or less fugitive.

Whenever our organs act freely, and according to the ordinary laws of organization, our thoughts are agreeable, the pleasure is sometimes very vivid. But, when the functions are deranged, the organs wounded, or diseases have impaired their action, our internal sensations are painful, according to the nature of the injury. This is the reason why pain constitutes an important part of the study of a physician.

It is probable, that the nerves, which pass directly from the brain or spinal marrow, are the organs for the transmission of internal sensations. The physiologists of the present day, however, appear to attribute this function to the nerve, which is called the *great sympathetic.** We cannot say positively, that it is not

* Why should we consider the great sympathetic as a nerve? The ganglions and filaments which pass from it, or lead to it, have no analogy with the nerves, properly so called. Their colour, form, consistence, disposition, structure and chemical properties, are all different. Nor have they any greater analogy in their vital properties. We may scratch or cut a ganglion, or even tear it, without the animal appearing to be conscious of it. I have often made these experiments on the ganglions in the necks of horses and dogs. Similar operations performed on a cerebral nerve, will produce the most terrific pain. We may take away all the ganglions of the neck, and even the first ganglions of the thorax, without any sensible derangement in the functions, even of those parts to which we can trace them. What reason is there then for considering the system of ganglions as constituting a part of the nervous system? Would it not be more philosophical, and especially more useful to the future progress of physiology, to acknowledge that at this moment the uses of the great sympathetic are entirely unknown? We shall be confirmed in this idea by reading on the subject. Every author has some peculiar opinions on this point. We hear, e. g. the ganglions

so; but it is impossible to admit this doctrine, as it is not founded on any fact, or direct experiment.

The causes which modify internal and external sensations are innumerable. Age, sex, temperament, seasons, climate, habit, and individual character, each separately modify sensation; but, when they are united, the result is much more manifest. The difference of sensations among different individuals is expressed by the common maxim, "every one has his own way of feeling, and thinking."

It is probable that only internal sensations exist in the fœtus. We are led to suppose this by the motions which it executes, which appear tobe the result of impressions arising spontaneously in the organs. It is well known, from experiment, that when any derangement arises in the circulation or respiration of the mother, it is followed by the motions of the fœtus. All the senses are not found to exist at birth, or for sometime afterwards. Taste, touch, and smell are alone exercised, sight and hearing are developed later, as we have observed in the history of each particular function. Each sense must pass through different degrees, before it can arrive at perfection, it is indispensable, therefore, that each sense should receive, what may properly be called, an *education.* If any person will follow an infant in the developement of its senses, he may easily satisfy himself of the modifitions they undergo before arriving at perfection.

In those sensations which are produced by distant objects, the education is slow and difficult; in those which arise from contact, it is much more prompt, and appears to be easily effected. During this education of the senses, that is, in our infancy, the sensations are confused and weak. But afterwards, especially those of young people, are remarkable for their number and vivacity. At this age they are deeply engraved in the memory; and, of consequence, are destined to constitute a part of our intellectual existence, during the remainder of our lives. With the progress of age our sensations lose their vivacity, but become more perfect, as

considered as nervous centres, small brains, collections of cineritious substance for the nourishment of the nerves, &c. If we inquire after the proof by which these authors establish their doctrines; we are surprised not to find any, but that their assertions are mere freaks of the imagination.

respects exactness, after arriving at the adult age. In old age they grow weak, and are produced with slowness and difficulty. This effect is more remarkable in those senses which makes us acquainted with the physical properties of bodies, but much less so in those by which we become informed of their chemical properties. These last senses, those of taste and smell, alone preserve any activity in decrepitude, the others are nearly extinguished, by the diminished sensibility, and the successive physical alterations which they undergo.

OF THE FUNCTIONS OF THE BRAIN.

The human understanding exhibits phenomena so different from any thing else which natural objects present, that they have been referred to a particular being, which has been regarded as an emanation of the deity. This idea seems too agreeable and consoling, for us to allow the physiologist to question its truth. But the severity of language, or rather of logic, which physiology now exacts, requires that we should treat the human understanding, as if it were the result of the action of an organ. By deviating from this rule, some men, very justly distinguished for their intelligence, have fallen into some most serious errors; by following it, we have, on the contrary, the great advantage of still pursuing the same method of study, and of rendering very plain, things which have been generally considered as beyond the grasp of the human mind.

The Brain.

The brain is the material organ of thought, which is proved by innumerable facts, and experiments.

Under the denomination of brain, I include three parts, distinct from each other, though they are all united at certain points; they are, the *cerebrum*, *cerebellum*, and *medulla spinalis.*

In each of these principal divisions, we find distinct parts, which have a sort of separate existence, so that there is nothing more complicated and difficult in anatomy, than the study of the organization of the brain. In proportion, however, to the importance of the function of this organ, anatomists and philosophers have at all times devoted themselves to its dissection. The result of this is, that the anatomical history of the brain is one of the most perfect parts of anatomy. Very lately, this subject has been much elucidated by the publication of the works of Messrs. Gall and Spurzheim, and to the investigations to which they have given rise.*

The brain being of an extremely delicate texture, and its function being easily destroyed by the least derangement, nature has taken uncommon care to protect it from injuries arising from the contact of surrounding bodies.

Among the protecting parts of the brain which have received the denomination *tutamina cerebri*, we remark the hair, the scalp, the muscles, the pericranium, the bones of the skull, and the dura mater, which are particularly destined to guard the cerebrum and cerebellum.

The Hair.—By its quantity and arrangement, the hair is very suitable to weaken the effects of blows upon the head. As it is a bad conductor of caloric, it forms a covering, the texture of which being loose, intercepts a large number of small masses of air; it is well disposed, therefore, to preserve the head of a uniform temperature, in some sort, independently of the air, or surrounding bodies. As it is impregnated with an oily substance, it imbibes but a small quantity of water and dries rapidly. The hair being also a bad conductor of the electric fluid, it, in some degree, insulates the head, hence the head is less likely to be affected by this fluid.

It is easy to conceive how the scalp, the muscles which cover the cranium, and the pericranium, concur in protecting the brain; it will not be necessary, therefore, to insist on this point.

The Cranium.—But of all the means of protecting the brain, the most efficient, is the collection of bones, called the *cranium*, which completely envelop this organ. In consequence of the hardness and strength of this envelope, and its spherical form, all pressure or percussion, exerted upon any given part of the head, is distributed from this point to all the rest, and is, therefore, less felt by the brain. If, for example, a man receives a blow from a cane on the top of his head, the motion will be propagated in every direction, and will extend even to the middle

* Vide Appendix, No. 2.

part of the base of the cranium, that is, even to the body of the sphenoid bone; if the blow be given upon the forehead, the motion will be propagated towards the middle of the occipital bone. In this transmission of motion through the bones of the cranium, it has been supposed, that these bones experienced a slight, but reciprocal displacement, which were with difficulty distinguished, in consequence of the disposition of the different articulations. There are, however, good reasons to believe that the cranium resists, as if it were a single bone.

Changes of form in the brain.—Authors have not dwelt, sufficiently, upon the fact, that it must, necessarily, happen, that the cranium will change its form whenever it is pressed, or struck smartly. The softness of the cerebral mass will enable it to endure slight changes in the form of its envelope, without any serious injury. The softer the brain is, the more able it will be to suffer strong pressure, or percussion, without inconvenience. This is the reason why new-born infants, in whom the bones of the cranium are very moveable upon each other, often have the head strongly compressed, and even sensibly deformed, without any injurious consequences. The same things exist, in a degree, in children at a more advanced age, who receive, without danger, violent blows upon the head. In the early periods of life, the brain is much softer than in the adult.*

Dura Mater.—The dura mater is so arranged as to protect the brain, as it were, against itself. Indeed, without the folds which are formed by this membrane, viz. the falciform process, and the tentorium, one hemisphere of the cerebrum would press upon the other, when the head was inclined to one side; and the brain would compress the cerebellum, when the head was erect; so that the different parts of the organ would destroy each other.

Medulla Spinalis.—If we compare the precautions taken by nature, to preserve the cerebrum and cerebellum from external injury, with those which we find she has guarded the spinal marrow, we shall be led to infer, that this last is of greater impor-

* If the brain were perfectly fluid and homogeneous, whatever might be the changes in the form of its envelope, there would not result any injurious effects. But, as the brain is of a soft consistence, and not homogeneous, it follows, that violent blows are often followed by serious consequences, such as concussion, extravasation of blood, abscess, &c.

tance than the first; or that its texture, being more delicate, requires extreme care. This is, in fact, the case. The spinal marrow holds a rank, in the animal economy, at least as important as the cephalic portion of the nervous system. The least shock wounds it, the least compression destroys its functions in a moment. It was, therefore necessary that the vertebral canal which contains it, should afford a powerful protection. This end is attained in a manner so perfect, that nothing is more rare than an injury of the spinal marrow. The vertebral column necessarily unites great solidity with great mobility. It is the centre of motion in all the efforts of the body; it is also the centre of motion in the action of the extremities, and executes very extensive movements itself.

We cannot here enter into the details of this admirable mechanism. We refer the reader to the "Anatomie Descriptive de Bichat," for a further account of this subject.

Arachnoides.—Besides the different envelopes of the brain, of which we have spoken, and the dura mater, which encloses it, in its whole extent, this organ is surrounded by a very delicate serous membrane, which is called the *arachnoides*, the principal use of which, is to form a very thin fluid, which lubricates the brain. The arachnoides penetrates into all the cavities of the brain, and forms there a perspiratory fluid.

The Pia Mater.—The manner that the blood-vessels enter and pass out from the brain, is extremely curious. We shall enter, more particularly, into a consideration of this subject, when we come to treat of the circulation. We shall only remark here, that the arteries, before penetrating into the substance of this organ, are reduced to capillary vessels, and that the veins affect the same disposition in passing out from this substance. As these very fine blood-vessels communicate with each other, by numerous anastamoses, the result is, that there is formed on the surface of the brain, a vascular net-work, which has, very improperly, been called the *pia-mater*. This net-work is introduced into the cavities of the brain, and it is this which forms the *plexus choroides.*

We shall not pretend to give here a description of the anatomy of the brain; but shall limit ourselves to some general reflections on the subject. Almost all authors who have given an anatomical description of the brain, in their works, have neglected to observe a proper strictness in the expressions they have employed, and have suffered their minds to be influenced by preconceived and hypothetical opinions. It is indispensable, for the future progress of anatomy and physiology, that we should employ terms which are precise, to avoid, as much as possible, hypothetical expressions, and, above all, to reject the supposition that the nerves terminate or unite at any given point of the brain; that the soul has its seat in any particular part of this organ; or that the nervous fluid is secreted by a certain portion of the cerebral mass, while the rest serves as a conductor of this fluid, &c. From neglecting this method, those authors who have described the brain, have presented false ideas, expressed in an obscure manner.

When we speak of the brain, we mean the organ that fills the cavity of the cranium, and the vertebral canal. To facilitate the study of it, anatomists have divided it into three parts, viz. the *cerebrum*, the *cerebellum*, and *medulla spinalis*. This, however, is purely a scholastic distinction; in fact, these three parts form but one organ. The spinal marrow is no more a prolongation of the cerebrum and cerebellum than these are an expansion of the spinal marrow.

To say that the cineritious substance of the brain produces the white part, is entirely gratuitous. In truth, the cineritious, no more produces the white part of the brain, than a muscle produces the tendon in which it terminates, or the heart the *aorta*. In this respect, the anatomical system of Messrs. Gall and Spurzheim is essentially defective.

In man, that part which is properly called the brain, is more voluminous than in other animals. The dimensions of this organ are proportioned to those of the head. Individuals differ very much in this respect. Generally speaking, the volume of the brain is in a direct proportion to the capacity of the mind. It would be incorrect, however, to suppose that every man who has a large head, must, necessarily, be possessed of a superior intellect, because many causes, besides the volume of the brain, may increase the size of the head. But it is, nevertheless, very rare that a man distinguished for his mental faculties, is not found to have a large head. The only means of ascertaining the volume of the brain in man, during life, is to measure the dimensions of the cranium. No other method, not even that proposed by Camper, can be relied upon.

The brain of man presents more numerous circumvolutions, and deeper inequalities than other animals. The number, volume, and arrangement of the circumvolutions are various. In some brains, they are very large, and in others, they are numerous and small. Their disposition differs in each individual. Those of the right side are not arranged like those of the left. It would be an interesting point to determine, whether there exists any relation between the number of the circumvolutions, and the perfection or imperfection of the intellectual faculties; between the modifications of the mind, and the disposition of the individual, and the arrangement of the cerebral circumvolutions.

The volume and weight of the cerebellum, differ in different individuals, and at different periods of life. In the adult, the cerebellum is equal to the eighth or ninth part of the cerebrum; but it forms only the sixteenth or eighteenth part in new born infants. We do not find circumvolutions on the surface of the cerebellum, but it is divided into lamellæ, each being separated by a furrow. The number and arrangement of these lamellæ differ, in different individuals. We may here repeat the observation, which was made above, in speaking of the cerebral circumvolutions. An Italian anatomist, Malacarne, is said to have found three hundred and twenty-four of these lamellæ in the cerebellum of an idiot, while in other individuals he found more than eight hundred.

The substance of the cerebrum is soft and pulpy; its form is easily altered; in the fœtus it is almost fluid; it has more consistence in childhood, and still more in the adult. We find, also, that the degree of consistence varies at different points of the organ, and in different individuals; the odour is insipid, and resembles that of the semen, and remains for many years in dried brains.

We find two substances in the brain. The one is grey and the other white. The first is called the *cineritious*, and the other, the *medullary* substance. The *medullary* portion constitutes the greater part of the organ, it occupies more particularly the interior of it, and that part which corresponds to the base of the cranium. It has a fibrous appearance, and possesses more firmness than the cineritious part; and it forms a great part of the spinal marrow, particularly near its surface.

The *cineritious* substance, which is sometimes called cortical, forms a lamina, varying in thickness on the external part of the cerebrum and cerebellum; and is likewise found in some of the internal parts. In some parts, it is covered by medullary matter, in others, it seems intimately combined with it, and sometimes these two substances are disposed in laminæ or alternate striæ. We find other parts in the brain distinguished by their colour, viz. yellow, black, &c.*

When we examine the cerebral substance, by means of a microscope, it appears to be formed of an immense number of globules, of unequal magnitude, they are said to be about eight times smaller than those of the blood. In the medullary substance, they are disposed in right lines, and have the appearance of fibres; in the cineritious substance, they seem to be thrown confusedly together.

According to M. Vauquelin, there is no difference in the chemical composition of the different parts of the nervous system. The analysis of the cerebrum, cerebellum, spinal marrow, and nerves, exhibit the same results.

He found them composed of

Water - - - - - - - - -	80.00
White fatty matter - - - - -	4.53
Red fatty matter - - - - -	0.70
Osmazome - - - - - - -	1.12
Albumen - - - - - - -	7.00
Phosphorus - - - - - - -	1.50
Sulphur and Salts, such as	
Acid phosphate of potash }	
——————— lime }	5.15
——————— magnesia }	

The arteries of the brain are large, and are four in number, viz. the two internal carotids, and the two vertebrals, they have a peculiar arrangement, on which we shall more particularly insist under the article, *arterial circulation.* We shall only

* Sœmmering distinguishes four substances in the brain, viz. white, grey, yellow, and black.

observe here, that they are, principally, placed at the inferior part of the organ; that, by their anastomoses, they form a circle, and that they are reduced down to capillary vessels before they penetrate into the substance of the brain. It has been computed that the brain receives about one eighth of all the blood which passes from the heart. But this estimate is only an approximation; the quantity varying, no doubt, according to a great variety of circumstances. We know, from recent dissections, that the cerebral arteries are accompanied by filaments of the great sympathetic nerve; we can trace these filaments with ease, along the principal branches of the arteries. It is to be presumed, therefore, that they accompany them even in their most minute ramifications. But it is not to be concluded, necessarily, from this disposition, which is common to all the arteries, that the brain receives nerves. The filaments of the great sympathetic have here, as they have every where else, an evident connexion with the parietes of the arteries.

The cerebral veins.—These have also a peculiar arrangement. They occupy the superior parts of the organ, they have no valvular structure; and they terminate in canals, situated between the laminæ of the dura mater. We shall particularly investigate this subject under the head, *venous circulation.* No lymphatic vessels have yet been detected in the brain.

Observations made on the brain of man, and living animals.

It has been ascertained from the heads of new-born infants, the cranium of which is still membranous, and from those of adults, where the brain has been denuded by wounds and disease, that it has two distinct movements. The first is evidently synchronous, with the pulsation of the heart and arteries, the second, with respiration; that is, the organ seems to sink down upon itself, at the moment inspiration takes place; the opposite phenomenon occurs during expiration. According as the respiration is more or less strong, are these motions of the brain manifest. These two motions are very readily remarked in animals; it is not easy to explain why the existence of this phenomenon should lately have been called in question. It is thought that these motions are very slight, when the integrity of the cranium is preserved, and that they are necessary to the perfection of the cerebral functions; but this is a point which has not been demonstrated.

The cerebrum and cerebellum exactly fill the cavity of the cranium, in the dead body; of consequence, during life, when these parts receive a great quantity of blood, and their vessels are distended by it, and when there is an abundant vapour continually forming upon its surface and that of its cavities, the organ must endure a considerable pressure, which will, of course, vary in intensity with the quantity of blood which penetrates into, and passes out from the brain.

As the spinal marrow does not exactly fill the cavity of the vertebral canal, it is not as likely to be compressed, as the cerebrum and cerebellum. But the pia mater exerts upon the spinal marrow a manifest pressure, so that it is nearly in the same condition as the brain, as respects pressure. It appears that this pressure is indispensable to the functions of the organ; for whenever it is suddenly diminished or increased, the functions are suspended; but if this be done gradually, the cerebral functions continue.

The uses of the brain in the economy are extremely important and numerous. It is the organ of intelligence; it is the source of all those means by which we act upon external bodies; it exercises an influence, more or less marked, upon all the phenomena of life, and it establishes a relation, always active, between the different organs; or, in other words, it is the principal agent of the sympathies. We shall now consider it under the first character.

OF INTELLIGENCE.

Whatever may be the number and diversity of the phenomena which pertain to the human understanding, however different they may appear from the other phenomena of life, and though they may be evidently dependent upon the soul, it is indispensable to consider them as the result of the action of the brain; and not to distinguish them, in any way, from other phenomena, which are dependent on organic action. Indeed, the functions of the brain are absolutely governed by the same general laws as the other functions; they are developed, and they decay, with the progress of age; they are modified by habit, sex, temperament, and individual character; they are deranged, depressed, and exalted, by disease and the physical lesions of the brain pervert or destroy them. In a word, like every other organic action, they are not susceptible of explanation by us, and in investigating them, laying aside hypothesis, we must be governed by observation and experience alone. It is also necessary to guard ourselves against the impression, that the study of the functions of the brain is more difficult than that of the other organs, and that it belongs exclusively to metaphysics. By adhering rigorously to observation, and scrupulously avoiding all explanations or conjectures, this study becomes purely physiological. Perhaps it is even easier than many of the other functions, from the facility with which we are enabled to produce and examine its phenomena.

The study of the understanding has not heretofore been considered as constituting an essential part of physiology. One science is specially devoted to this, and is called *ideology.* Persons desirous of examining this interesting subject, *in extenso*, may consult the works of Bacon, Locke, Condillac, Cabanis, and especially the excellent work of M Destutt Tracy, entitled "Elements of Ideology." We shall confine ourselves to some of the fundamental principles of this science.

The innumerable phenomena which constitute the human understanding,* are but modifications of the faculty of perception. When we examine them with attention, we shall find no difficulty in confirming this observation, the truth of which is generally admitted by modern metaphysicians.

We may divide the faculty of perception into four principal modifications.—

1st. Sensibility, by which we receive impressions from within or from without. 2d. Memory, or the faculty of re-producing impressions, or sensations previously received. 3d. The faculty of perceiving the relation between sensations, or judgment. 4th. Desire or will.

Of Sensibility.

All that we have said of sensations, generally, will apply to sensibility; for this reason, we shall here limit ourselves to

* The human understanding has been called the spirit, the faculties of the soul, intellectual faculties, cerebral functions, &c.

observing, that this faculty is exerted in two very different modes. In the first, the sensation passes unobserved by us; we do not perceive it. In the second we take notice of it, and are conscious of its existence. It is not sufficient then, that a body acts upon our senses, or that the nerve transmits the impression which it has received to the brain, it is not even sufficient that this organ receives this impression. In order for a perfect sensation to exist, it is necessary that the brain should perceive the impression received by it. An impression thus perceived, is called in ideology, a *perception*, or *idea*.

We may easily prove upon ourselves the existence of these two modes of sensibility. It is easy to see, for example, that a crowd of objects are continually acting upon our senses, without our noticing them. This effect depends in a great measure upon habit.

Sensibility varies, infinitely, in different individuals. In some, it is very obtuse, in others it exists in an extraordinary degree; generally, in those who are well constituted, there is a medium between these two extremes.

In infancy and youth, the sensibility is vivid, and remains nearly in the same state until the adult age; but as old age advances, it becomes materially diminished; so that the decrepit are nearly insensible to all the causes of ordinary sensations.

Of the Memory.

The brain is capable, not only of receiving impressions, but also of re-producing those, which had before existed. This cerebral action, when it produces recently acquired ideas, is called *memory*. It is called *recollection*, when the ideas have been long acquired. An old man, who recalls the events of his youth, *recollects them;* a man who retraces the sensations which he has experienced during the past year, *remembers them.*

Reminiscence is an idea reproduced, which we do not recollect to have previously received.

Like sensibility, the memory is very much developed in infancy and youth. At this period of life, the mind acquires knowledge with the most facility, especially of that kind which does not require much reflection; such as languages, history, and the descriptive sciences. In the progress of age, the memory becomes weakened, it diminishes in the adult, and is almost lost in old age. We sometimes see individuals, however, whose memory remains, even at the most advanced periods of life. This advantage is generally derived from constant exercise, as has been sometimes observed in actors. But it is, undoubtedly, true, that it often exists to the injury of the other intellectual faculties. The more vivid the sensations are, the more easily are they remembered. The memory of internal sensations, are almost always confused. Certain diseases of the brain completely destroy the memory.

Of Judgment.

There can be no doubt, that judgment is the most important of the intellectual faculties. It is by this faculty that we acquire all our knowledge. Without it our life would be purely vegetative, and we should have no idea of the existence of other bodies, or even of our own, as all our knowledge is the direct result of the faculty of judgment. To form a judgment, is to establish a relation between any two ideas, or collections of ideas. When I judge that a work is good; I perceive that the idea of goodness agrees with the book which I have read; I establish a relation, I form an idea different from what sensibility, or memory would have enabled me to form. A series of judgments, connected together, constitute reasoning. We may readily conceive how important it is for us to form correct judgments; that is, that we do not establish any relations but those which really exist. If I judge a substance which is poisonous, to be salutary, I incur the danger of losing my life; the false judgment which I have formed will be very injurious to me. The same remark will apply to all false judgments. Nearly all the misfortunes to which man is exposed, morally speaking, have their origin in errors of judgment; crime, vices, and bad conduct, are all the results of false judgments.

It is the object of one science, viz. logic, to teach us to reason justly. But sound judgment and good sense, or erroneous judgment, and mental weakness, are the results of organization. It is impossible to change in this respect; we must remain as nature has formed us. Some men are endowed with the valuable gift of discovering relations which have never before been perceived. If these relations should happen to be important, so as to confer great benefit on mankind, their possessors are said to be men of genius; but if they relate to objects of less importance, they are said to possess wit, or imagination. It is, principally, by their manner of perceiving relations, or judging, that men differ from each other. Vivacity of sensation appears to be injurious to correct judgment; this is the reason why this faculty becomes more perfect with age.

Of the Desire or Will.

We give the name of will to that modification of the faculty of perception, by which we experience desires. In general, it is the consequence of our judgment, and it is worthy of remark, that upon this faculty, our happiness or unhappiness necessarily depends. When our desires are satisfied, we are happy; we are unhappy, on the contrary, when we cannot gratify them. It becomes us, therefore, so to direct our desires that we shall be enabled to gratify them. We must avoid desiring, for example, those things, which it is impossible for us to obtain; and it is still more important for us not to desire those which are injurious, for in this case we cannot escape unhappiness, whether we indulge them, or not. Morality is a science, the object of which is to give the best possible direction to our desires. Desires have been generally confounded with that cerebral action which presides over the contraction of the voluntary muscles. I think it advantageous to the student that this distinction should be established.

Such are the four principal distinctions into which the faculty of perception has been divided; they have been called the *simple faculties of the mind.* It is the combination and reaction of these faculties upon each other which constitutes the intelligence of man and the higher order of animals. There is, however, this remarkable difference between man and other animals; they remain always in, nearly, the same state, their faculties receiving but little improvement, in the course of their lives; but man derives improvement from every object by which he is surrounded, and is thus enabled to attain that intellectual superiority, by which he is distinguished.

The faculty of generalising, which consists in creating signs to represent ideas, to assist thought by means of these signs, and to form abstract ideas, is characteristic of the human understanding; it is this which enables it to acquire that prodigious extension which we see in civilized nations. This faculty of generalising can, of course, only exist in a state of society. An individual who should have lived alone, and who should not have had any intercourse with his fellow creatures, even in his early years, of which there have been several examples, would not differ much from brute animals, he would only possess the four simple faculties of the mind. It is the same with those individuals to whom nature, by a defective organization, has denied the faculty of employing signs, or of forming these abstractions, or general ideas; they remain all their lives in a perfect state of brutality, as we observe in ideots.

In general, the physical circumstances in which a man finds himself placed, will have a powerful influence upon the development of his understanding. If he is enabled to procure subsistence with ease, and to satisfy all his physical wants, he will be in a situation favourable to the cultivation of his mind, and a free development of his mental faculties. But if he can only, with difficulty, satisfy the demands of nature, his mind, being chiefly directed to that single point, will necessarily remain in a rude and imperfect state, as is always found to be the case among savages and slaves.

OF INSTINCT AND THE PASSIONS.

Nature has not abandoned animals to themselves. It is necessary that each should exercise a series of actions from which results that astonishing harmony, which we witness among organized beings. To induce animals to concur in this, and to execute those actions for which each is designed, nature has given them *instinct;* that is, desires, inclinations, wants, by means of which they are continually, and forcibly compelled to fulfil the designs of nature.

Instinct may exist in two different ways, viz. with, or without a knowledge of the end. The first may be called *intelligent instinct*, the second *blind*, or *brutal instinct.* The first is, more particularly, the prerogative of man; the second pertains to animals.

In examining with care the numerous phenomena which depend upon instinct, we find that it has two principal objects; the first is the preservation of the individual, and the second that of the species. There are as many instincts as species of animals, varying according to their organization. As organization varies among individuals, these instincts are much more remarkable in some, than others.

In man, we find two kinds of instincts, the first relates to his condition as an animal, and is always exhibited by him in whatever situation he is found. This kind of instinct resembles that of animals. The other arises from the social state. Without doubt it depends, like every other vital phenomenon, upon organization. But this is never developed but in a state of civil society, for this purpose it is necessary that he should enjoy those advantages which accompany this state.

The first, which may be called animal instinct, includes hunger, thirst, a want of cloathing, and habitation; a desire of happiness, or of agreeable sensations, and the fear of pain and death; a disposition to destroy other animals, or even those of his own species, when dangers are to be feared from them, or advantages to be derived from their destruction; the venereal appetite; attachment to children; tendency to imitation; and a love of society, which leads to civilization, &c. These instinctive sentiments are constantly acting upon man, and induce him to concur in the order established among organized beings. The natural wants of man are more numerous and various than those of other animals, in a direct proportion to his intelligence. In every other respect, he enjoys a decided superiority over all other animals.

When man lives in a state of society, he is enabled easily to satisfy all the wants, of which we have been speaking, he has then *leisure;* in other words, to satisfy these first wants, requires but a small portion of his time and faculties. Then arise new wants, which may be called *social.* Such is our desire to have a very vivid consciousness of our existence; a feeling which, the more it is indulged in, the more difficult it is to satisfy, because, as we have already observed, our sensations become weakened by habit.

This fondness for vivid impressions, joined to a continual diminution in the strength of our sensations, causes inquietude and vague desires, which are increased by the importunate recollection of the vivid sensations that we formerly experienced. For the purpose of removing this state, we are compelled to have recourse to a continual change of objects, or to increase the intensity of the same sort of impressions. From this arises an inconstancy, which does not permit us to fix any limits to our wishes, and a progression of desires which are annihilated by indulgence, but afford us no gratification; hence arises *ennui*, that unceasing source of misery to civilized man, when he has no employment.

This desire of vivid sensations, is counterbalanced by a love of repose, or indolence, which acts so powerfully on the higher classes of society. These two opposite sentiments modify each other, and from their action and reaction, result a love of power, of consideration, and of wealth, which enables us to indulge both. These two instinctive sentiments are not the only ones which arises from the social state; it developes a crowd of others, less important, indeed, but not less real. Our natural wants, also, become remarkably altered; instead of hunger, a most capricious taste is often substituted; for the venereal desire, feelings of a very different nature, &c. Natural modify social wants, and *vice versa;* and when, in addition to this, we recollect that age, sex, temperament, &c. have a strong influence upon all our desires, we may form some idea of the difficulties which a study of the instinct of man presents. This part of physiology has been heretofore scarcely noticed.

We may at the same time remark, that an increase of the social wants, is always accompanied by a corresponding development of the understanding. There is no comparison, as relates to the capacity of the mind, between man in the more opulent class of society, and as he is found in that condition, where al the physical energies are barely sufficient to provide for his first wants.

Of the Passions.

In general, we understand by the term passion, an extreme and exclusive instinctive sentiment. A man in a passion neither sees, hears, nor is conscious of any thing, but the sentiment by which he is excited; and, as the violence of this sentiment renders it disagreeable, and even painful, it has received the name of passion or suffering. Passions have the same end as instincts; they induce animals to act according to the general laws of living bodies.

We see in man passions, which he has in common with other animals, which consist in vehement, animal desires; and others, which display themselves in a state of society only; these are the social wants, very much increased.

The animal passions relate to a double end, as we have before remarked, in speaking of natural instinct, viz. the preservation of the individual, and that of the species.

To the preservation of the individual belong, fear, anger, grief, hatred, and excessive hunger, &c.; to that of the species, the venereal appetite, jealousy, and furious anger, when the offspring is in danger. Nature has attached great importance to this class of passions, which exist in their full force in man, in a state of society.

The passions peculiar to a state of society, are but the social wants carried to an extreme degree. Ambition is but the excess of a love of power; avarice, an excessive desire of fortune; hatred, and vengeance are but natural and impetuous wishes to injure those who have injured us; a passion for play, and almost every other vice, is the result of a love of violent excitement; violent love is but an exaltation of venereal desires, &c.

Among the passions, some weaken or extinguish themselves when they are satisfied; others, again, increase by indulgence. Happiness is often produced by the first, as we sometimes see in love and philanthropy; but unhappiness is necessarily attached to the last, examples of which are constantly furnished by the ambitious, avaricious, and envious.

If wants develope the powers of the understanding, the passions are the principal cause of every thing very great which has been accomplished by man. The great poets, heroes, criminals, and conquerors, have always been men who were strongly under the influence of the passions.

In speaking of the passions, shall we say, with Bichat, that they reside in the organic life, or, with the ancients and some moderns, that anger is in the head, courage in the heart, and fear in the semilunar ganglion, &c.? Passions are but internal sensations, they cannot therefore be said to have a seat; they result from the action of the nervous system, particularly of the brain; they do not, therefore, admit of explanation. We are capable of observing, directing, calming or extinguishing, but not of explaining them.*

OF MOTION.

The functions which we have now examined, depend entirely on the faculty of perception. It is by this faculty that we arrive at a knowledge of the objects which surround us, and of ourselves.

To terminate the history of the functions of relation, it only remains for us to speak of those functions by means of which we act upon foreign bodies, impress upon them the changes which we judge necessary, and express our sentiments and ideas to those by whom we are surrounded. These functions are but different shades of the same phenomenon, *muscular contraction.* So that the faculty of perception on the one side, and muscular contraction on the other, constitute really all our life of relation. We shall first define muscular contraction, in general, after which, we shall treat of its principal results, voice and motion.

Of Muscular Contraction.

Muscular contractility, which has also been called animal, and voluntary contractility, is not a vital property, at least in the sense which we attach to this word. It results from the

* This would be the place to treat of the use of the different parts of the brain in intelligence and the instinctive faculties, but this subject is very conjectural, and too little understood to enter into an elementary work. We have been occupying ourselves with direct experiments upon this point, and shall publish the result, as soon as we think them worthy of public attention.

successive or simultaneous action of several organs, and ought, therefore, to be viewed as a function.

Apparatus of Muscular Contraction.

The organs which concur in muscular contraction are the brain, nerves, and muscles. It has not yet been ascertained that some parts of the brain serve exclusively for sensibility, and intelligence, and that others are only employed in muscular contraction; no successful attempt has yet been made to divide the nerves into those of feeling and of motion. This distinction is without foundation.* For this reason, having spoken above of the brain and nerves in their anatomical relation, we have nothing further to add on this subject, but shall now say something of the muscles.

Of the Muscles.

All the muscles, taken collectively, are called the muscular system. The form and disposition of the muscles vary infinitely. Muscles are formed by the union of a certain number of muscular fasciculi, which are again composed of still smaller bundles; these again are formed of fasciculi of a smaller volume; and thus, by excessive subdivison, we get at a fibre extremely small, and which we can no farther divide, but which might probably be farther divided, if our senses and means of division were more perfect. This fibre which is indivisible by us, is called *the muscular fibre.* There have been many speculations as to its form, volume, disposition, and the arrangement of the molecules which compose it. It is longer or shorter, according to the muscles of which it constitutes a part; almost always straight, it does not divide, nor is it confounded with other fibres of the same kind; it is enveloped in a cellular tissue, extremely delicate; it is soft, and easily torn in the dead body, but, on the contrary, in the living body, it exhibits a resistance, in proportion to its volume, which is surprising; it is essentially composed of fibrine and osmazome; it receives much blood, and, at least, one nervous filament. Some anatomists have pretended to explain how the blood vessels and nerves act, when they arrive in the tissue of the muscular fibres, but nothing satisfactory has been advanced upon this point.

* The late experiments of Mr. Charles Bell, and the author himself, go far to shew, that the above assertion is incorrect.—*Trans.*

Each muscular fibre is attached, at its two extremities, by fibrous prolongations, (tendons or aponeuroses) which are the conductors of its force, when it contracts itself. Muscular contraction, as it exists in the ordinary state of life, supposes a free and easy exercise of the brain, and the nerves which are sent to the muscles, and of the muscles themselves. Each of these organs must receive arterial blood, and the venous blood not be permitted to remain in its tissue, for too great a length of time; if either of these conditions be wanting, muscular contraction is either impossible, perverted, or very weak.

Phenomena of Muscular Contraction.

When a muscle contracts itself, its fibres grow shorter and harder, more or less suddenly, without any oscillation, or preparatory hesitation; they immediately acquire such a degree of elasticity, that they become susceptible of vibrations, or of producing sounds. The colour of the muscle does not appear to change at the moment it contracts, but it has a tendency to displace itself, which is counteracted by the aponeurosis. It has been doubted, whether a muscle is more voluminous in a state of contraction or relaxation; this does not appear to us to have been resolved, happily it is one of little importance. All the sensible phenomena of muscular contraction take place in the muscles themselves; but it is not the less certain, that these depend upon the action of the brain and nerves. Compress the brain of an animal, and it loses the power of contracting its muscles. Cut the nerves which are distributed to a muscle, and it becomes paralyzed. We are completely ignorant of the changes that take place, in the muscular tissue, during contraction. In this respect, muscular contractions cannot be separated from the vital actions, of which we can give no explanation. Not but there have been many attempts to explain, not only the action of the muscles, but also that of the nerves, and even of the brain, in muscular contraction, but there is no hypothesis which has yet been proposed, that can be considered at all satisfactory.

Instead of consuming our time in such speculations, which it is always easy both to invent, and refute, and which should long since have been banished from physiology; we may much more profitably employ ourselves in investigating muscular contraction, as it relates; 1st, to its intensity; 2nd, its duration; 3d, its rapidity; 4th, its extent.

Intensity of Muscular Contraction.—The degree of force with which the muscular fibres shorten themselves, is generally regulated by the action of the brain. It is, in general, submissive to the will, varying in degrees, in each individual. A particular organization of the muscles is favourable to the intensity of its contractions, this exists when the fibres are voluminous, firm, of a deep red colour, and presenting transverse striæ. With an equal effort of the will, they produce greater effects than those muscles, the fibres of which are small, smooth, and of a light colour. Nevertheless, when muscles, the fibres of which are of this last description, are placed strongly under the influence of the will, the intensity of the contraction may be very great; so that cerebral influence, and the disposition of the muscular tissue, are the two elementary principles, on which the intensity of muscular contraction depends.

It is rare that we find in the same individual, very energetic cerebral action, united with a disposition of the muscular fibres, favourable to intensity of contractions; it almost always happens, that these two principles are opposite to each other. When they happen to be united, they produce astonishing effects. This was probably the case with the Athleti of antiquity, and is sometimes observed in the jugglers of the present day. By the influence of the action of the brain alone, muscular power may be exerted to an extraordinary degree. We know very well the astonishing strength of some men in anger, that of maniacs, and of persons in convulsions, &c.

Duration of Muscular Contraction.—This is, in some degree, dependent upon the will, but it cannot be prolonged beyond a certain period, which varies in different individuals. After this, a sense of fatigue is induced, slight at first, but which at last increases to such an extent, that the muscle refuses to contract. The promptitude with which this sensation of fatigue is induced, is in proportion to the intensity of the contraction, and the weakness of the individual. To obviate this inconvenience, the different motions of the body are so calculated, that the muscles act successively, the contraction of each does not, therefore, continue long. We can thus explain why we do not remain long in the same position; why an attitude, which requires the strong and continued contraction of a small number of muscles, cannot be continued long. The sense of fatigue, which follows muscular contraction, is dissipated by a state of repose, after which the muscle recovers its power of contraction.

Rapidity of Muscular Contraction.—To a certain extent, rapidity of contractions depends on cerebral influence. This is proved by our ordinary movements; but it also sometimes depends upon habit. Observe, for example, what a difference exists, as relates to rapidity of muscular contractions, between a man who, for the first time, puts his hands upon the keys of a piano, and the same individual after he has been in the habit of practising for several years! We observe a very remarkable difference between individuals, as respects quickness of contraction, both in the common movements, and in those which require an appropriate exercise.

Extent of Muscular Contractions.—This is directed by the will, but it must necessarily vary with the length of the fibres, for long fibres must have a more considerable extent of contraction, than those which are shorter.

From what has been said, we perceive, that, in general, the will has a great influence upon the contraction of muscles. But this is not indispensable. In a great number of instances, these motions are executed, not only without its participation, but in opposition to it. We find many remarkable examples of this, in the effects of habit, passions, and diseases.

We must not confound muscular contraction, such as we have now described it, with the modification it undergoes in certain diseases, such as convulsions, spasms, tetanus, wounds of the brain, &c.* We must, likewise, take care not to confound that contraction, of which we are now speaking, with the phenomena which the muscles present for sometime after death. Without doubt, these phenomena are curious, and worthy of examination, but they certainly do not merit the importance which has been attached to them by Haller and his disciples; especially, as it is not proper to unite them, under the name of irritability, with the other modes of contraction, which are observed in the

* See Appendix, No. 3.

animal economy, and, particularly, with that of muscular contraction.

Modification of Muscular Contraction by Age.

It is only at the commencement of the second month that we can distinguish the muscles from the gelatinous mass, which constitutes the embryo. At this period, they do not present any of those characters, by which they are distinguished in the adult. They are then of a pale grey colour, slightly tinged with red; and receive but a small quantity of blood, comparatively speaking. They increase and develope themselves with the progress of its growth; though, even at the period of birth, they are small, flaccid, and indistinct. We must except, however, those which assist in digestion and respiration, which are developed, in a remarkable manner.

During infancy and youth, the nutrition of the muscles becomes increased; and they grow, particularly, in length. This is the reason of the slenderness and agreeable rotundity, which we observe in the forms of children and young persons. When a person arrives at the adult age, the form undergoes a total change; the muscles increase, and project strongly against the skin; the intervals which separate them being no longer filled with fat, projections and depressions are formed, which give to the body an entirely different aspect, from that of childhood. At this age, the muscles assume a greater degree of consistence, the colour becomes of a deeper red, and even the chemical characters are modified. We learn from daily experiments, that when the flesh of young animals is boiled, that the flavour, colour, and consistence of the broth, differ, very much, from that of an adult animal. It appears that the muscles of adult animals, contain more fibrine, osmazome, and the colouring matter of the blood, of consequence, more of iron.

The nourishment of the muscles diminishes sensibly in old age; they diminish in volume, grow pale, and become flaccid and unsteady, especially in the extremities, the contractility of the tissue is weakened, the fibre becomes coriaceous, and is torn with difficulty. The preparation of muscular flesh is also very different in our kitchens, according as the animal is young or old.

Muscular contraction undergoes nearly the same changes as the nutrition of the muscles. Weak, and hardly distinguishable in the fœtus, its activity is augmented at birth, increases rapidly in childhood and youth, acquires its highest degree of perfection in the adult age, and finishes by being nearly lost in the decrepid old man.

OF THE VOICE.

We understand by the voice, the sound produced in the larynx, at the moment the air traverses this organ, either to enter into, or pass out from the trachea.

For the purpose of explaining the mechanism, by which the voice is produced and modified, we shall say a few words of the manner in which sound is produced, propagated, and modified in wind instruments, especially in those which have the greatest analogy with the organ of voice.

In general, a wind instrument is formed by a straight or curved tube, in which the air is thrown into a state of vibration, by various processes. Wind instruments are of two sorts; the one is called a mouth, the other a reeded instrument.

The *mouth instruments* include the horn, trumpet, flageolet, flute, and the flute tube of the organ. In all these, the column of air is contained in the tube, which is the sonorous body. In order that it may produce sound, it is necessary that vibrations should be excited. The means employed for this purpose, vary according to the kind of instrument. The length, size, form of the tube, the openings formed in its side and its extremities, the force and manner with which the vibrations are excited, are the causes of the variety of sounds in different instruments. The nature of the substance of which they are formed, only influences the distinctness of the notes. The theory of these instruments, is precisely similar to that of the vibration of longitudinal cords. When we know the physical condition of one of these instruments, we can determine with accuracy, by calculation, the sound which it will produce. There is nothing obscure in this theory, except some point relative to the mouth piece, that is, the manner in which the vibrations are excited There is no very evident resemblance between this kind of instrument and that of the voice.

Reeded Instruments.—It is more important for us to understand reeded instruments, because the organ of the voice is of this kind. Unfortunately, their theory is much less perfect, than that of mouth instruments. We include, in this kind of instruments, the hautboy, bassoon, clarionet, and the organ of the human voice. We may divide this instrument into the reed and the body, or tube; the mechanism of these two parts is essentially different.

The reed is formed sometimes of one, and at others, of two thin plates, which are susceptible of moving very rapidly, and the vibrations of which are destined alternately to intercept, and transmit a current of air. This is the reason why the sounds thus produced, are not governed by the same laws, as those formed by elastic plates, free at one end, and fixed at the other, which excite immediately sonorous undulations in the open air. In reeded instruments, the reed alone produces and modifies the sounds. If the reed be long, the motions are extensive and slow, of consequence the sounds are grave. A short reed, on the contrary, produces, necessarily, acute sounds, because the alternate transmission and repression of the current of air, are more rapid. When we wish to draw from a reeded instrument a variety of sounds, it is necessary to vary the length of the reed. This is done by those who play upon the bassoon, clarionet, &c. when they wish to produce different sounds with these instruments.

We may add, however, as an important circumstance, that the elevation of the tone produced by an instrument depends, in part, on the elasticity, weight, and even form of the reed, and the intensity of the current of air; for when these circumstances vary, the length remaining the same, the tone alters.

We never employ the reed alone, but adapt it always to a tube, through which the air passes, when it is forced through the reed, and which must, for this reason, be open at both extremities. The tube has no influence upon the tone of the sound; it has only an influence upon the intensity, distinctness, and the possibility of enabling the reed to form articulate sounds. Those which produce the loudest sounds are conical tubes, which enlarge as they approach the part where the air escapes. If the cone be reversed, the sound becomes dull. But if two equal cones, opposed base to base, are adjusted to a conical tube, the sound becomes round and strong. The reason of these modifications have never been given by natural philosophers.

A column of air vibrating in a tube, can produce only a certain number of determinate sounds. In consequence of this, a reeded instrument, when it is long, can only transmit distinctly those sounds which it is intended to produce; it is also necessary to establish at first a certain proportion between the reed and the body of the instrument. Of consequence, when we wish to draw a succession of different sounds from the same reeded instrument, it is necessary not only to modify the length of the reed, but to modify also, in a corresponding manner, the length of the tube; now this end is attained by piercing the sides of the bassoon, clarionet, &c. with small holes. By opening or closing these, we can make the reed and the tube bear such a proportion to each other, as may be convenient. This agreement, likewise, enables us more easily, by means of the lips, to give the instrument the sound which we wish to produce. This influence of the tube is very remarkable in those instruments which are narrow, (clarionets and hautboys.) It is even to such an extent that the effect produced by the reed is very imperfect, if the tube be not suited to it. When the tubes are very large, as in organs, the reeds vibrate almost as freely as in the open air. We know not precisely what are the movements which take place in the air contained in such tubes, when they transmit the sound produced by the reed. We have seen above, that the reverse is the case in mouth instruments.

Apparatus of the Voice.

Inasmuch as the passage of the air through the larynx, is a condition absolutely necessary to the formation of the voice, we must include all the organs which produce this effect among the number of the vocal organs. There are many parts which assist in the formation or modification of the voice, but, before speaking of them, we shall more particularly insist here upon the larynx, which must be considered, more especially, as the organ of voice.

The Larynx.—Is placed at the anterior part of the neck, and forms that remarkable projection which exists between the tongue and the trachea, which varies according to the age and sex. It is smaller in children than in females, it is still larger in young men after the age of puberty, and is much more developed in the adult. The larynx not only produces the voice, but it is also the agent of its principal modifications. This is the reason why an exact knowledge of the anatomy of this organ is indispensable, if we wish to comprehend the mechanism of the voice. In consequence of not paying a sufficient attention to this point, very imperfect, or even false ideas have been propagated on this interesting subject. We cannot enter here into all the details of the structure of the larynx; but we shall dwell more particularly upon those parts which are most necessary to be known, many of which are, at present, but little understood.

Cartilages of the Larynx.—The larynx is composed of four cartilages, and of three fibro-cartilages; which form its frame or skeleton. The cartilages are the *cricoid*, the *thyroid*, and the two *arytenoid*. The thyroid is articulated with the cricoid by the extremity of its inferior horns. During life, the thyroid is fixed, relatively to the cricoid cartilage, which is contrary to the received opinions on this subject. Each arytenoid cartilage is articulated with the cricoid, by means of an oblong *facette*, and is concave transversely. The cricoid presents a *facette*, the disposition of which is analogous to that of the arytenoid cartilage, with this difference, that it is convex, where the corresponding part of the other is concave. Near the articulation is found a synovial capsule closed anteriorly and posteriorly, but loose laterally. Before the articulation is the thyro-arytenoid ligament, and behind a strong ligamentous fasciculus, which may be called the crico-arytenoid ligament, from its attachments.

Arranged as I have now described, the articulation will only permit the arytenoid cartilages to move laterally upon the cricoid. All motion anteriorly and posteriorly is impossible, as well as a certain see-saw motion that is mentioned in books on anatomy, which cannot be produced by any muscle. This articulation must be considered as a simple lateral ginglymus. The fibro-cartilages of the larynx, are the epiglottis, and two small bodies which are found above the upper part of the arytenoid cartilages, and which were called by Santorini *capitula cartilaginum arytenoidarum.*

Muscles of the Larynx.—A great number of muscles are attached mediately and immediately to the larynx. These muscles have been called *extrinsic;* they are destined to move the organ as a whole, either to elevate or depress it, or to carry it backward or forwards, &c. Besides these, the larynx has muscles, the use of which is to move one part upon another, these are called *intrinsic.* They are, 1st. The *crico-thyroid* muscles, the use of which is not to depress the thyroid upon the cricoid cartilage, as has been heretofore believed, but, on the contrary, it elevates the cricoid, making it approach the thyroid, or even causing it to pass a little under its inferior edge. 2d. The posterior *crico-arytenoid* and the lateral, *crico-arytenoid* muscles, the use of which is to carry the arytenoid cartilages outwardly, separating them from each other. 3d. The arytenoid muscle which draws together, and applies to each other the arytenoid cartilages. 4th. The *thyro-arytenoid,* which, is the most important to be known of all the muscles of the larynx, inasmuch as it is that, the vibrations of which produce vocal sounds. This muscle forms the lips of the glottis, the inferior, the superior, and lateral parietes of the ventricles of the larynx. 5th. Lastly, the muscles of the *epiglottis,* which are the *thyro-epiglottis,* and the *aryteno-epiglottis,* and some fibres which may be viewed as the *vestige* of the *glosso-epiglottis,* which exists in many animals. Contraction has an influence therefore on the position of the epiglottis.

Mucous Membrane of the Larynx.—The larynx is covered on its interior surface, by a mucous membrane. This membrane, in passing from the epiglottis to the arytenoid and thyroid cartilages, forms two-folds which are called the *lateral ligaments of the epiglottis;* they run together to form the superior and inferior ligaments of the glottis. Behind and in the tissue of the epiglottis we find a great number of mucous follicles, and some mucous glands. There exists in the thickest part of the ligaments of the epiglottis, a collection of these bodies which have been improperly enough called the *arytenoid gland.* Between the epiglottis, posteriorly, and the os hyoides and thyroid cartilage, anteriorly, we find a considerable bundle, of very elastic, fatty, cellular tissue, analogous to that which is found in the neighbourhood of certain joints. The use of this body has not yet been assigned. I conceive that it serves to facilitate the frequent gliding of the thyroid cartilage on the posterior face of the os hyoides, to keep the epiglottis separated superiorly from this bone, and at the same time to furnish an elastic support, which may favour the functions which this fibro-cartilage performs, in the voice, and deglutition.

Vessels and Nerves of the Larynx.—The blood vessels present nothing very remarkable. This remark, however, will not apply to the nerves of this organ, their distribution deserves to be examined with care. These nerves are four in number, viz. the superior laryngeals, and the recurrents, or inferior laryngeals.

The recurrent nerve is distributed to the posterior crico-arytenoid, to the lateral crico-arytenoid, and to the thyro-arytenoid muscles; none of its ramifications are transmitted to the arytenoid, or the crico-thyroid muscles. The superior laryngeal nerve, on the contrary, is sent to the arytenoid muscle, to which it gives a considerable branch; and to the crico-thyroideus it sends a filament less remarkable for its size than the mode of its transmission. In some cases, however, this filament does not exist, but then the branch of the external laryngeal nerve is larger. The remainder of the filaments of the laryngeal nerve are distributed to the muscles of the epiglottis, and to the mucous membrane which covers the entrance of the larynx. This part is endued with excessive sensibility.

Glottis, or Rima Glottidis.—These names are given to the opening between the thyro-arytenoid muscles and the arytenoid cartilages. In the dead body, the glottis presents a longitudinal opening or chink, about eight lines long, and two or three wide, and larger at the posterior, than the anterior part, where the two sides approach, so as to touch at the point where they are inserted into the thyroid cartilage. The posterior extremity of the glottis is formed by the arytenoideus muscle.

Ligaments of the Glottis, or the Vocal Chords.—When we bring the arytenoid cartilages together, so that their internal surfaces touch, the glottis is diminished about one third of its length; it then presents an opening not more than from one half, to a line in width, and five or six lines in length. The sides of the rima, are called the *lips of the glottis.* They present a sharp edge, directed upwards and inwards; and are principally formed by the thyro-arytenoideus muscle, and by the ligament of the same name, which covers, like an aponeurosis, the muscle to which it is strongly attached, and itself, covered by the mucous membrane, forms essentially the thin, or cut edge of the lip. These lips of the glottis vibrate during the production of the voice, and may be considered as *the reed* of the instrument.

Ventricles of the Larynx.—Above the inferior ligaments of the glottis, are the ventricles of the larynx, the cavity of which is more spacious than it seems to be at first; the external inferior and superior walls of which, are formed by the thyro-arytenoideus muscle, turned upon itself; the extremity or anterior wall is formed by the thyroid cartilage. By means of these ventricles, the lips of the glottis are perfectly insulated at their superior edge.

We see above the opening of the ventricles, two bodies which have a great analogy in their arrangement, with the vocal chords, and which form a second glottis above the first; these are called the *superior ligaments of the glottis.* They are formed by the superior edge of the thyro-arytenoid muscle, a little of the fatty, cellular tissue, and the mucous membrane of the larynx, which covers them before entering into the ventricles. Such are the observations which are easily made on the larynx in the dead body. I believe no one has ever examined the glottis in man during life; at least no one to my knowledge, has ever written on the subject. When we examine it in animals, dogs for example, we find that it enlarges and diminishes alternately. The arytenoid cartilages are carried outwards at the moment that the air penetrates into the lungs, and they approach and apply themselves to each other, at the instant the air passes out from this cavity.

Mechanism of the production of the Voice.

If we take the trachea and larynx of an animal, or man, and blow strongly into the trachea, towards the larynx, no sound will be produced, but a slight noise resulting from the friction of the air, against the walls of the larynx. If continuing to blow, we bring together the arytenoid cartilages, so that their internal surfaces are in contact, there will be produced a sound which has some resemblance to the voice of the animal from which the larynx was taken. The sound will be more or less acute or grave, according as the cartilages approach each other with more or less force; it will be more intense when we blow into the trachea with the most force. It is easy to see, by this experiment, that it is the inferior ligament of the glottis, which, by its vibrations, produces the sound.

An opening made into the trachea in man and animals below the larynx, deprives them of voice; this will be restored if the opening be stopped mechanically. I know a man who has been in this situation for many years; he can only speak when his cravat, which closes a fistulous opening in the larynx, is drawn tight. The same effect is produced when the larynx is opened below the inferior ligaments of the glottis.

On the contrary, should a wound exist above the glottis, affecting the epiglottis and its muscles; the superior ligaments of the glottis, or even the superior part of the arytenoid cartilages, the voice will still remain. Indeed, when the glottis of a living animal is laid bare, when it cries out, it is easy to perceive that the voice is formed by the vibration of the *vocal chords*.* From this I think it is placed beyond a doubt, that the voice is produced in the glottis by the movements of its inferior ligaments. If this be considered as well established, can we, on philosophical principles, account for the formation of the voice? The following explanation appears to me the most probable. The air forced from the lungs, passes at first into a large canal, which soon contracts, and it is then compelled to pass through a narrow passage or chink, the sides of which are two vibrating plates, which like the plates in reeded instruments, transmit and intercept alternately the passage of the air, and cause, at the same time, sonorous undulations in the current of air which is transmitted.

But why then, it may be asked, when we blow strongly into the human trachea after death, is there no sound produced analogous to the human voice? Why is the paralysis of the *intrinsic muscle* of this organ, always followed by the loss of voice?

* This is the name given by Ferrein to the lips of the glottis.

and why is an act of the will required for the formation of vocal sounds? The answer is easy.—The ligaments of the glottis do not acquire the power of vibrating, like the plates in reeded instruments, except when the thyro-arytenoid muscles are contracted; of consequence, in all those cases where this is not the case, no voice will be produced.

Experiments upon animals perfectly agree with this doctrine. Divide the two recurrent nerves, which, as we have said before, are distributed to the thyro-arytenoid muscles, and the voice is immediately lost. Cut but one, and the voice is only half lost. I have, however, seen many animals utter very sharp cries, when they felt severe pain, after the recurrent nerves had been divided. But these cries were extremely analogous to sounds produced with the larynx of the animal after death, by blowing into the trachea, and at the same time, approximating the arytenoid cartilages; a phenomenon which is readily explained, by the distribution of the nerves of the larynx. The recurrents being divided, the thyro-arytenoid muscles cease to contract, and the result is aphonia. But the arytenoid muscle, which receives its nerves from the superior laryngeal, contracts itself, and at the moment when a strong expiration takes place, one of the arytenoid cartilages being applied to the other, the rima glottidis is contracted, by which the thyro-arytenoid muscles are thrown into a state of vibration, though they are not contracted.

Intensity or Volume of the Voice.

This depends, like all other sounds, on the extent of the vibrations.* The greater the force, with which the air is expelled from the chest, the greater will be the extent of the vibrations of the vocal chords; and the longer these chords are, that is, the greater the capacity of the larynx, the more considerable will be the extent of the vibrations. A strong person, whose breast is large, and in whom the dimensions of the larynx are considerable, presents those circumstances, which are the most favourable to intensity of the voice. But when this person becomes sick, and his strength reduced, his voice loses much of its intensity,

* Probably, the intensity of the sound depends upon other causes, besides the extent of the vibrations; and it must be the same with the intensity of the voice.

for this simple reason, that it can no longer expel the air from the chest with great force.

Children, women, and eunuchs, in whom the larynx is proportionally smaller than in the adult man, have also naturally the voice much less intense than his.

In the ordinary production of the voice, it results from simultaneous movements of both sides of the glottis. If one of these sides loses the faculty of exciting vibrations in the air, the voice will necessarily lose the half of its intensity, supposing the expiratory force to remain the same. We may satisfy ourselves on this point, by dividing one of the recurrent nerves of a dog, or by examining the voice of a person attacked with complete hemiplegia.

Of the Note of the Voice.

Each individual possesses a peculiar note or kind of voice by which he is known; the different ages and sexes are marked in this manner. The note of the voice then presents infinite modifications. We are ignorant of the precise physical circumstances on which this depends; the female note, however, and that which is observed in children and eunuchs, is generally found connected with a peculiarly soft state of the cartilages of the larynx. The masculine note of voice, which is sometimes observed in females, on the contrary, seems to be connected with an osseous state of these cartilages, particularly the thyroid.

Note then is a modification of sound, of which no very satisfactory account has yet been given.

Of the different Tones or extent of the Voice.

The sounds which the larynx in man is capable of producing are extremely numerous. Many distinguished authors have endeavoured to explain their formation, but these when examined, will be found to be rather comparisons, than explanations. Thus Ferrein considered the ligaments of the glottis as chords, and he explained the different tones of the voice, by the different degrees of tension, of which he supposed they were capable, &c. others have compared the larynx to a wind instrument, to the lips of the horn, or to the human lips in the act of whistling. But all the explanations which have heretofore been given, err radically in this, that they are founded upon a consideration of this organ in the dead body, while the only true mode of investigating the subject, is a minute attention to the anatomy of the part, and a careful examination of the phenomena exhibited during life. I have endeavoured to supply this deficiency, and will now state the results which I have obtained.

I laid bare the glottis of a dog, making an incision between the os hyoides and thyroid cartilage; and examined the part carefully while he was howling. I found, when the sounds were grave, that the ligaments of the glottis vibrated through their whole length, and that the expired air passed out through the whole extent of the glottis. When the sounds were acute, the ligaments did not vibrate at their anterior, but only at their posterior part, the air only passing through that portion of the glottis which vibrated, the opening, of course, being diminished. When the sounds became very acute, the ligaments no longer vibrated, except at the arytenoid extremity; and the expired air then passed out at this portion of the glottis. It appeared that the acuteness of the sound increased until the glottis became entirely closed, when the air could no longer pass through the larynx, and the sound ceased. The principal use of the arytenoideus muscle being to close the glottis at its posterior extremity, it must be the chief agent in producing acute sounds. I was desirous of knowing what effect would be produced upon the voice by the division of the two laryngeal nerves which supply this muscle. I had recourse to some experiments for this purpose, and found that when this was done, the voice of the animal lost all its acute sounds; and that it likewise acquired an habitual gravity, which it had not before possessed.

The structure of the larynx in man and in the dog is so much alike, that we cannot doubt that the same phenomena take place in both. There is one circumstance which must have a certain influence on the tones of the voice; it is the contraction of the thyro-arytenoid muscles. The more strongly these muscles contract, the more will their elasticity be increased, and the more susceptible they will become of vibrating rapidly, and of producing acute sounds; on the contrary, the less they are contracted, the more grave the sounds will be. We may also presume, that the contraction of these muscles concurs powerfully in closing the glottis, particularly its anterior half.

It would appear, then, that the larynx represents a reeded instrument with a double plate, the tones of which are more acute as the plates are shortened, and more grave as they are elongated. But although the analogy be generally just, it does not necessarily follow, that it is in every respect complete. In fact, the common reeds are composed of rectangular plates, fixed on one side and free on the other three; in the larynx, the vibrating plates are nearly rectangular, but they are fixed by three sides instead of one. Again, we raise or fall the notes in the common reeded instrument, by varying its length; in the plates of the larynx, it is the size which varies. Lastly, in musical instruments we cannot employ reeds, the plates of which can, every instant, alter their thickness and elasticity, as happens in the ligaments of the glottis. From what has been said, it can easily be conceived, that the larynx may produce the voice and vary its tones, somewhat after the manner of reeded instruments, without our undertaking minutely to explain all the particularities in its mode of action.

It has heretofore been believed that the tube, which conveys the air to the reed, has no influence on the sound produced. M. Biot relates an experiment of M. Grenié, which proves the reverse of this. It is not impossible that the lengthening or shortening of the trachea, which is the tube for conveying the air to the larynx, may have some influence in the production of the voice, and on its different tones.

Having examined the *reed* of the organ of voice, it will be now proper to consider the tube which the vocal sound traverses, after having been produced. In proceeding from below, upwards, the tube is composed, first, of the interval comprehended between the epiglottis, before, and the lateral ligaments, on the sides, and the posterior walls of the pharynx; second, of the pharynx, posteriorly and laterally, and of the most posterior part of the base of the tongue, anteriorly; third, sometimes of the mouth, sometimes of the nasal cavities, and at other times of both.

This tube may be elongated or shortened, enlarged or diminished; being susceptible of assuming an infinite number of different forms, it will fulfil, very well, the office of the body of a reed instrument; that is, it will possess the power of arranging itself, so as to harmonize with the larynx, and thus favour the production of all the numerous tones of which the voice is susceptible. It will increase the intensity of the vocal sounds by assuming a conical form; by enlarging, externally, it will give them an agreeable rotundity; or by arranging the external opening conveniently, it will nearly suppress them, &c.

Until natural philosophy has determined with precision, the influence of the tube in reeded instruments, we can, at best, only form probable conjectures, respecting the influence of the tube, in the formation of the voice. We can only illustrate this point by a small number of experiments, which relate to those phenomena which are the most apparent.

The larynx elevates itself during the production of acute sounds, and is depressed, when they are grave; of consequence, the vocal tube is shortened in the first case, and elongated in the second. We may conceive that a short tube is most favourable, to the transmission of acute sounds, and that a long one is most advantageous in those which are grave.—At the same time, that the tube changes its length, it likewise alters its size; a circumstance, which is remarkable, because, as we have seen above, the size of the tube influences its facility of transmitting sound.

When the larynx descends, that is, when the vocal tube is elongated, the thyroid cartilage is depressed, and separated from the os hyoides, to the whole extent of the thyro-hyoidian membrane. By this separation, the gland of the epiglottis is carried forward, and comes to lodge itself in the concavity of the posterior face of the os hyoides; this gland necessarily draws after it the epiglottis; from which results a considerable enlargement of the inferior part of the vocal tube.

The opposite phenomenon happens, when the larynx is elevated. We then see the thyroid cartilage raise itself behind the os hyoides,* displacing and pushing backward the gland of the epiglottis, this pushes the epiglottis in its turn, so that the vocal tube becomes thus very much contracted. In imitating this movement upon the dead body, we may satisfy ourselves, that this contraction may be carried to five-sixths of the size of

* The thyro-hyoidian muscles appear more particularly destined to produce the movement, by which the thyroid cartilage passes behind the os hyoides.

the tube. Now we adapt a large tube to a reed, which is to form grave sounds, and, on the contrary, a narrow tube to one, which is intended to convey acute sounds. We can then, to a certain extent, account for the changes of size, which take place in the vocal tube.

The presence of the ventricles of the larynx, immediately above the inferior ligaments of the glottis, appears to be intended to insulate those ligaments, so that they may vibrate freely. When foreign bodies are introduced into these ventricles, or when they are covered with a tenacious mucous, or a false membrane, the voice is either entirely lost, or very much weakened.

From its form, position, elasticity, and the movements impressed upon it by its muscles, the epiglottis seems to constitute an essential part of the apparatus of voice. But we may inquire, what are its uses? We have seen already, that it assists powerfully in the contraction of the vocal tube, but we may suppose, that it performs a still more important function.

M. Grenié, who has invented so many ingenious and useful modifications of reeded instruments, did not arrive at these results, by a single effort, but had to pass through a long series of intermediate inquiries. At one period of his investigations, he wished to augment the intensity of the sound, without changing the reed. To effect this, he was obliged to augment, gradually, the intensity of the current of air; but this, though it rendered the sounds stronger, had likewise the effect of elevating the note. To remedy this inconvenience, M. Grenié could find no other method, than to place obliquely in the tube, immediately above the reed, a flexible, elastic tongue, resembling very much the epiglottis; we may suppose, from this, that the epiglottis assists in giving to man the power of swelling vocal sounds, without elevating the tone.

The intensity of the voice is evidently influenced by the vocal tube. The most intense sounds, that the voice can produce, require that the mouth should be opened widely, the tongue a little drawn back, the veil of the palate raised up, closing all communication with the nasal fossæ. In this case, the pharynx and the mouth evidently perform the office, and resemble, with considerable exactness, those tubes of reeded instruments, which enlarge at the part, where the air passes out, and the effect of which, is to augment the intensity of the sound, produced by the reed. If the mouth be partly closed, the lips projected forwards, and more or less drawn together, the voice will acquire an agreeable rotundity, but will lose its intensity. This result is easily explained, by what has been before said of the influence which the form of the tube exerts in reeded instruments. For the same reasons, every time the vocal sound passes the nasal fossæ, it becomes weaker, because the form of these cavities is extremely well adapted, to diminish the intensity of sounds. If the mouth and nose be closed at the same time, no sound will be produced.

We have already seen, in speaking of the production of the voice, that a great number of modifications in the note, arise from the changes, which take place in the thickness and elasticity of the lips of the glottis. The tube also produces a great number of others, varying according to its length and capacity; the form and contraction of the pharynx; the position of the tongue, and the veil of the palate; according as the sound passes out, either entirely through the mouth, or nose, or by these two cavities at the same time; the form of the mouth and nose of the individual; the presence or absence of the teeth; the volume of the tongue. &c.—The note of the voice, I say, will be modified by all these circumstances. Whenever, for example, the sound traverses the nasal fossæ, the tone will be disagreeable, or, as it is commonly called, *nasal*. Persons who think that the nasal cavities can augment the intensity of vocal sound, by resounding through them, deceive themselves; as these cavities can only produce the reverse effect; also whenever, from any cause, the sound is introduced into them, the voice becomes dull or nasal.

Independently of the numerous modifications determined by the tube of the vocal organ, as relates to the intensity and note of the voice, it produces another modification, much more important, by transmitting it or intercepting it alternately. By this means, a vocal sound is divided into small portions, which have each a distinct character, because each is produced by a particular movement of the tube. The influence thus exerted by the vocal tube, is called the *faculty of articulation*, which presents an infinite number of differences in individuals corresponding with the peculiar organization of the vocal tube.

Thus far we have treated of the human voice, in a general manner; we shall now speak of its principal modifications, viz. the *cry*, or *native voice;* the *voice*, properly so called, or the *acquired voice; speech*, or *articulate voice;* singing, or *appreciable voice.*

Of the native Voice, or Cries.

This is an unappreciable sound, which, like all others produced by the larynx, is susceptible of variety, both in tone, intensity, and note. A cry is easily distinguished from all other vocal sounds; but, as its character depends upon its note, it is impossible to explain, physically, the reason of the difference between other vocal sounds and it.

In whatever condition man may be found he is always capable of uttering this sound. The new-born infant and the decrepit old man; the savage and the civilized man; those who have been dumb from their birth, and ideots; are all capable of uttering cries. We must consider, therefore, crying as essentially depending upon organization; this will be still more apparent from examining its uses.

Use of Cries.—By a cry, we express vivid sensations, whether they arise from within or without, whether they are agreeable or painful. By cries we express our most simple, instinctive wants, and natural passions. There are cries of joy and pain; of anger and of fear, &c. The social wants and passions, not being indispensably connected with organization, but requiring a state of civilization to develope them, have no peculiar cries.

Cries generally include the most intense sounds that the organ of the voice is capable of forming. Most frequently its note wounds the ear, and acts strongly upon those who are exposed to its effects. These establish important relations between man and his fellow creatures. A cry of joy imparts pleasure, a cry of grief excites pity, and the cry excited by fear carries terror to a distance, &c. This kind of language is found among most animals, and is in fact nearly the only one they possess. The singing of birds can only be considered as a modification of their cries.

Of Acquired Voice.

Man in his ordinary condition, that is in a state of society, and when he is endowed with the sense of hearing, soon perceives, even in his early infancy, that his fellow creatures produce sounds, which are not cries. Having remarked this, by the instinctive force of imitation, he is soon able to form analogous sounds, this we call an *acquired voice.* A deaf child cannot make these remarks, he, therefore, can never acquire the power of making these sort of sounds.

The voice does not appear to differ from cries, except in intensity and note, for it is formed of unappreciable sounds, of which the ear cannot distinguish accurately the intervals.

Inasmuch as the voice is the result of hearing and of an intellectual effort, it cannot be developed unless both these conditions exist. Children who are deaf from birth, cannot form any idea of sound; and ideots are not capable of establishing any relation between the sounds which they hear, and those which they are capable of producing, they have therefore no voice; although the vocal apparatus in both, may be fitted to form and modify sounds, as well as in those of individuals whose conformation is the most perfect. For the same reason, those individuals, who have been very improperly called savages, from their having wandered alone in the forest from their infancy, do not possess voice, because the understanding does not sufficiently develope itself in this insulated state, and no necessity for mental exertion exists.

The tone, intensity, and notes of the voice are all susceptible of numerous modifications by the action of the larynx; the vocal tube also exerts a powerful influence upon the voice. Speech and singing are but modifications of the acquired voice.

It is difficult, perhaps impossible, to say how man has reached that degree of perfection by which he is enabled to represent his intellectual operations by modifications of the voice, to compose languages, and especially to invent the alphabet. These inquiries are undoubtedly curious and useful, but not indispensable, and besides do not properly belong to physiology; it is the mechanism of language which alone concerns us.

Language is composed of words, which are the signs of our ideas, and words are formed by the letters, or sounds of the alphabet, which are, for the most part, but modifications of the voice. Grammarians, distinguish letters into vowels and consonants, but this is not a proper physiological distinction. *We* may distinguish them into those which are true modifications of the voice, and those which are formed independently of the voice.

Vocal Letters.—The letters which are formed by the voice in the languages of Europe, are, *a*, as it is pronounced in English in the word, *hall;* (French) in *â* in *hâle*, and *a*, *è*, *é*, *e*, French mutes; *i*, *o*, Italian; *o*, *eu*, *u*, in French; and *u*, in Italian. Each of these letters may be modified; this we express when we say that it is long or short. These are the vowels of grammarians. The other vocal letters are, *b*, and *p*, (*labial consonants;*) *d*, and *t*, (*dental consonants;*) *l*, (*palatal consonant;*) *g*, and *k;* (*guttural consonants;*) *m*, and *n*, (*nasal consonants.*)

The formation of the vowels requiring the vocal tube to be open, depends upon the form it affects at the time the voice is produced. The vocal consonants suppose that the tube is closed, and result from the manner of its being opened at the moment the voice is formed. The existence of these last letters is then instantaneous.

Non vocal Letters.—The other letters, *f*, and *v*, the two sounds of *th*, in English; *s*, *z*, *ch*, *j*, *r*, *h*, and *x*, in Spanish, and *χ*, in Greek.

These letters are produced by the friction of the air against the walls of the mouth, and are of consequence independent of vocal sounds, and may be prolonged as long as the air continues to pass out from the lungs.

Each letter, both vowels and consonants, is produced by a certain disposition or particular movement of the vocal tube: the tongue is the principal agent in the formation of some; in others the lips or teeth, and in others the sound traverses the nasal fossæ, &c.

In order that the pronunciation may be correct, it is necessary that the vocal tube should be well formed. When there is any lesion of this part, e.g. a perforation of the vault of the mouth, or of the *uvula*, or veil of the palate; a loss of the teeth; or a swelling or paralysis of the tongue, the power of articulation becomes altered, and may be even lost.

The simple noise made by the air in traversing the larynx may be sufficient for pronunciation, as happens when we speak very low. Persons who have completely lost their voice, still continue to pronounce with so much distinctness, as to be understood at a certain distance.

By different combinations of letters, we form sounds more or less compounded, which are words. The formation of words is different, in different languages. In the north of Europe, the consonants are numerous, and the words are rough and difficult to pronounce; though this is not perhaps the true cause of it. In the south, the vowels are most numerous; and the sounds are generally soft and harmonious.

Accent.—The same sound is not always continued in the pronunciation of words. In articulating, the voice is raised and lowered, and its intensity and note varied, in a manner which varies in every language. The mode of these variations constitutes *accent*, or the pronunciation peculiar to each country.

Speech.—To articulate, or pronounce, is not to speak. A bird may be taught to *pronounce* words, or even sentences, but not to speak. Man is alone endowed with the faculty of speech, which is the most powerful means of expressing his intelligence; he alone attaches a meaning to the words which he pronounces, and to the arrangement which he gives them. He would, therefore, not possess speech unless he had understanding. In fact the greater number of ideots never speak, they articulate sounds vaguely, but do not, and cannot attach any meaning to them.*

Of Singing.

The voice in singing differs from other sounds produced by the larynx in this, that it is formed of appreciable sounds, of which the ear distinguishes easily the intervals, and perceives their agreement. These characters do not exist either in cries, or in speech, the sounds of which are unappreciable. Dodart has asserted, that in singing, the larynx undergoes an oscillatory movement from below, upwards; but his assertion is not confirmed by experiment. It is probable that in singing the ligaments

* See Pinel on Insanity.

of the glottis assume a particular arrangement, which enables them to form appreciable sounds.

We remark very important differences among individuals, in the extent, intensity, and note of the voice, in singing. In a common voice, there are about nine notes between its highest and its lowest tones; the most extensive voice does not much exceed two octaves, in full and well formed sounds.

There are two sorts of voices, the grave and the acute. They differ from each other by about one octave. In general, men have grave voices; those whose voice is the most grave may form acute sounds by taking what is called the *falsetto*. Women, children, and eunuchs, are generally found to possess acute voices. By adding all the notes of an acute, to those of a grave voice, they extend to nearly three octaves. It does not appear that any individual has ever possessed a voice of this extent, in which the sounds were clear and agreeable. Musicians establish also distinctions in base voices; high counter, tenor, base, &c.*

But the differences which exist between different voices do not alone regard extent. There are *strong voices* the sounds of which are strong and noisy; there are *soft voices*, the sounds of which are sweet and like those of the flute; *fine voices* the sounds of which are full and harmonious; *just*, *false*, *flexible*, *light*, *hard* and *heavy voices*. Some have their good sounds irregularly distributed; some in their *base*, some in their *treble*, others between.

Singing, like speech, is an effect of a state of society; it supposes the existence of hearing and intelligence. It is, in general, employed to paint our instinctive wants, passions, and different states of mind; joy, sadness, successful or unsuccessful love have each their peculiar songs.

Singing may also be articulate. Then, instead of expressing simply sentiments, it becomes the means of expressing a great number of the acts of the understanding, but particularly of those which are connected with the social passions.

Declamation is a particular sort of singing; though the intervals of the tones are not entirely harmonious; nor are the tones themselves completely appreciable. It appears, that among the ancients, declamation differed much less from sing-

* Dictionnaire de Musique, J. J. Rousseau.

ing, than among the moderns It was probably analogous to what is called the *recitative* in modern operas.

The languages in the south of Europe, which are strongly accentuated, that is, vary their tones very much in simple pronunciation, are very suitable for singing.

Inspiratory Voice.—All the modifications of the voice which we have examined are produced by the air passing out from the breast. The voice may also be formed at the moment the air traverses the larynx to penetrate into the trachea. But this *inspiratory voice*, is hoarse, unequal, and of small extent; we cannot, but with difficulty, vary the tones; in a word, from the very character of the phenomenon, we can perceive that it does not pass according to the ordinary laws of the animal economy. We can both speak and sing during inspiration. We are ignorant of the modification which the lips of the glottis undergo in the production of *inspiratory voice.*

The art of Ventriloquism.

Inasmuch as man possesses the power of varying indefinitely the appreciable and unappreciable sounds of his voice, and can change at pleasure, in a thousand ways, its intensity and note, nothing can be easier than to imitate exactly the different sounds which strike upon his ear; this in fact he executes under a variety of circumstances.

Many persons imitate perfectly the voice and pronunciation of others; hunters imitate the different cries of their game, and succeed, by these means, in attracting them into their snares. The faculty which some persons possess of imitating different sounds, has been made a profession of by some individuals, who have been supposed to have received from nature an organization different from other men. But this is a mistake; they only possess the organs of speech and voice well arranged, so that they can readily execute the sounds which they wish to produce.

The principles on which this art rests, are easy to comprehend. We know from experience; that sounds are altered by a variety of circumstances; e. g. that they become weakened, less distinct, and change their tone when they are at a distance from us. When a man descends into a well, and speaks to those who are above him, his voice does not arrive at their ears until it has undergone several modifications, arising from distance, and the form of the canal which it has passed through. If then a person has carefully remarked these modifications, and exerts himself to imitate them, after a little practice he will be able to produce this accoustic illusion; and we can no more avoid being deceived by it, than we can prevent our seeing objects larger than they actually are, when we examine them through a magnifying glass. The deception will be complete, if he employ other illusions to distract the attention.

The better the talents of the artist, the more perfect and numerous the illusions will be; but we must guard ourselves from supposing that the ventriloquist* produces voice and articulate sounds, differently from other persons. His voice is formed in the common manner, but it is modified by the artist in its volume and tone. As relates to his pronouncing words without moving his lips, it is because he employs words in which there are no labial consonants, which unavoidably require the motion of the lips to perform them. In one respect we may say that this art is to the ear, what painting is to the eye.

Modification of the Voice by Age.

The larynx is proportionally very small in the fœtus, and the new born infant; its small volume is contrasted with the os hyoides, the tongue, and other organs of deglutition, which are very much developed; it is rounded, and the thyroid cartilage does not project from the neck The lips of the glottis, the ventricles, and the superior ligaments are very short, in proportion to what they are afterwards, for the thyroid cartilage being but little developed, the space which they occupy is necessarily inconsiderable. The cartilages are also flexible, and are far from possessing the consistence which they afterwards acquire.

The larynx preserves these characters until about the period of puberty; at this time, a general revolution takes place in the animal economy. The evolution of the genital organs, determines a rapid increase in the nutrition of many of the other organs, especially that of the voice. The great increase in the

* The term ventriloquist, and other words of a similar import, were employed in the infancy of science, but it is evident that we ought not to admit them now in scientific language.

nutritive powers is first apparent in the muscles, afterwards, but more slowly, it is manifested in the cartilages, when the general form of the larynx becomes modified. The thyroid cartilage developes itself at its anterior part, and projects from the neck, but much more strongly in the male, than in the female. From this circumstance results a considerable elongation of the lips of the glottis, or of the thyro-arytenoid muscles. This circumstance is much more worthy of remark than the general enlargement of the glottis, which takes place at the same time. These changes in the larynx, though rapid, are not sudden, they require six or eight months before they are finished.

After the age of puberty, the larynx undergoes no other very remarkable change; except that its volume somewhat increases, and the projection of the thyroid cartilage becomes rather more prominent. In man, the cartilages ossify partially; in old age this process continues, and at last becomes nearly complete; the gland of the epiglottis decreases, and the intrinsic muscles, especially those which form the lips of the glottis, diminish in size, become less deep coloured, lose their elasticity, and at last undergo modifications, similar to those of the rest of the muscular system.

The production of the voice being dependent upon the passing of air into the chest, and the fœtus being plunged in the fluid of the amnios, it is of course incapable of forming sounds. But at the moment of its birth, the infant produces sharp, and intense sounds. *Vagitus*, is the name which has been given to this cry of infants, by which it expresses its wants and feelings; we may recollect that this is the object of its cries. Before the end of the first year, the infant begins to form sounds different from crying. These sounds are at first vague and irregular, but they soon become more and more distinct; at this time nurses begin to teach them to pronounce the most simple, and at last the most complicated words.

The pronunciation of children is different from that of adults; this is owing to the great difference which exists in the structure of their organs. In children, the teeth are still concealed in the alveolar processes; the tongue is comparatively large; the lips project more than is necessary to cover the anterior part of the jaws when they are brought in contact; and the nasal cavities are but little developed.

By degrees, and in proportion as the organs of pronunciation approximate those of the adult, children articulate distinctly the different combinations of letters. They do not learn to form appreciable sounds, or to sing, for the most part, until long after they have acquired the faculty of speech. These different sounds are what we have called the *acquired voice*, and are never formed by the child when it is deaf; the sounds it utters can only be considered a modification of the *vagitus*. Until the age of puberty, the larynx and lips of the glottis, remain proportionally very small, and the voice is entirely composed of sounds which are acute. It is then, physically impossible for the larynx to produce grave sounds.

At the age of puberty, particularly in men, the voice undergoes a remarkable modification. It acquires in a few days, sometimes very suddenly, a grave note, essentially different from what it exhibited before; it falls generally an octave. In some cases the voice is nearly lost, and does not entirely return for some weeks; frequently there remains for a time, a remarkable hoarseness, young men often form very acute sounds, when they intend to produce those which are grave. It is therefore, at this time, impossible for them to produce appreciable sounds; or to sing.

This state of things continues frequently for a year, after which the voice gets its natural note, which remains during life; but we sometimes meet with individuals, who, at this time, lose for ever the faculty of singing; and others, whose voices before this period were rich and extensive, afterwards become indifferent and limited.

The gravity which the voice acquires depends, evidently, on the development of the larynx, and especially on the elongation of the lips of the glottis. As these parts cannot extend posteriorly, they are lengthened anteriorly; at this period also the larynx becomes prominent, forming what is called the *pomum Adami*. In females, the larynx does not undergo this increase of size, the voice therefore generally remains acute.

The voice preserves nearly the same characters from puberty until the approach of old age; at least its modifications, during this interval, are inconsiderable, and chiefly respect its note and volume. But as old age approaches, the voice becomes essentially altered; its note is changed, and its extent diminished; and singing is more difficult, the sounds resembling cries, and being produced with difficulty and labour. The organs of pronunciation are altered, the teeth being shorter and often lost. All these phenomena become more remarkable as old age advances, the voice becoming weak, tremulous, and broken. The same remarks apply to singing; the defects in both cases arising from the imperfection in the muscular contraction of the part, the slowness in the movements of the tongue, the loss of the teeth, and the proportionally increased length of the lips, &c. all of which must necessarily have a strong influence on the pronunciation.

Relations between Hearing and Voice.

We have already spoken of the connexion between hearing and voice. It is such, that an infant deaf from its birth, is necessarily dumb; that a person who has a false ear, has necessarily a false voice; that an individual whose hearing is imperfect, is instinctively induced to talk loud. But the larynx in those who have been deaf from birth, is by no means incapable of producing voice; it has been before observed that they utter cries. Of late, by different processes, persons deaf and dumb from their birth have been taught to speak, so as to maintain a conversation; but their voice is hoarse, rough, and unequal. I believe, however, that there has been no instance where a deaf and dumb person has been taught to sing.

There have been some instances of persons who have acquired hearing, at an age when they could give an account of their sensations. Among all, the voice has been developed soon after the individual has acquired the sense of hearing.

The *Memoirs of the Academy of Sciences* for the year 1703, contain an example of this; which occurred in a young man of Chartres, who was twenty years of age. "Who, to the great astonishment of the whole city, began suddenly to speak." It appears, from his account of himself, that about three or four months before, he had heard the bells, and was extremely surprised by this new and unknown sensation. He observed about the same time water escape from his left ear, after which he heard perfectly with both ears. For three or four months he listened without attempting to speak to those about him, accustoming himself to repeat, in a very low voice, those words which he understood, strengthening himself in the pronunciation, and the ideas attached to the words. At last he broke silence, and spoke, though imperfectly. Immediately learned theologians were called to interrogate him," &c.

It is unfortunate for science that this young man was not observed by physicians, perhaps his history might then have been found more interesting.

A similar occurrence took place in Paris a few years since; a young man who had been deaf and dumb from his birth, was cured of his deafness by doctor Itard, by means of injections made into the drum, through an opening formed in the membrana tympani. He at first heard the sounds of the bells in the neighbourhood, which produced a very vivid emotion; he was immediately seized with pain in the head, and vertigo. The next day he was sensible of noises made in his apartment; in twenty-fours hours afterwards, he was able to distinguish the voice of persons who spoke to him. Then his delight became extreme, he could not satiate himself with hearing his friends speak; "his eyes" says Professor Percy, "seemed to seek the words upon their lips." His voice was not slow in developing itself; it formed at first but vague sounds, and in a short time he could stammer out a few words, but he pronounced them badly, and like a child. It was sometime before he could pronounce compound words, or those which contained many consonants. An organ was suddenly played in his presence; when he immediately began to tremble, and turned pale, and was near fainting; afterwards he experienced all those transports which we can imagine to be caused by a very vivid, but unknown pleasure; his flushed cheeks, sparkling eyes, rapid respiration, and quick pulse announced a sort of delirium, an intoxication of pleasurable feelings. No doubt, many other surprising and interesting phenomena would have been observed in this young man, if disease had not removed him from the philosophical physicians who attended upon him.

Of Sounds Independent of the Voice.

Independently of the voice, man can produce at pleasure a great number of appreciable, and unappreciable sounds; such as the noise which we make in the act of spitting or snuffing, that, by which we call a horse, and the imitation of the sound of drawing a cork from a bottle, whistling through the lips or teeth, either in expiring or inspiring, and a multitude of other noises which result from the movement of different parts of the mouth, or from the manner that the air penetrates into that cavity, or passes out from it. It is not easy to account for the mechanism of these different sounds, particularly those which are appreciable, as that of whistling; we can only approximate this point.

OF ATTITUDES AND MOVEMENTS.

Muscular contraction not only produces the voice but presides also over our movements and attitudes.

The explanation of the movements and attitudes of man consists in the application of the laws of mechanics to the organs which execute them. Our attitudes and movements being exceedingly various, in order to explain them, it would be necessary to have recourse to all the laws of mechanics. No one has ever executed this labour in a satisfactory manner; they have generally limited themselves to those movements and attitudes which are the most frequent, and to the application of the most simple principles of mechanics.

The Mechanical Principles which are necessary to understand the Movements and Attitudes.

The line in which the weight of a body acts, is called the *vertical line.* In every part of a body the vertical line passes through different points, but there is one point where all these lines cross each other; this is called the *centre of gravity.*

The *state of equilibrium* of a heavy body, placed upon a horizontal plane, is when a perpendicular falling through the centre of gravity upon the horizontal plane, passes between those points on which the body rests.

The *equilibrium* of a heavy body upon a horizontal plane is firm, in proportion as the centre of gravity of the body is near the plane, and the surface upon which it rests is extensive.

The *base of support* is the space included between those points on which a body is applied to the plane.

Of two hollow columns, formed of an equal quantity of the same materials, and of the same height, that which has the largest cavity will be the strongest.

Of two columns of the same diameter, but of different heights, the highest will be the weakest.

The greatest weight that a spring with small flexions can support, is proportional to the square of the number of flexions *plus* one; so that if the spring presents three curves, it will support a weight sixteen times heavier than if it had none.

Of Levers.

We define a lever to be an inflexible instrument which turns upon a fixed point. We distinguish in this instrument three parts, viz. the *fulcrum*, *the part to which the resistance*, and *that to which the power* is applied. According to the respective positions of the fulcrum, the power, and the resistance, the lever is of the *first*, *second*, or *third kind.* In the lever of the first kind the fulcrum is between the resistance and the power; the resistance being at one extremity, and the power at the other The second kind of lever is when the resistance is between the power and the fulcrum; the fulcrum and the power occupying the two extremities. Lastly, in the lever of the third kind, the power is between the resistance and the fulcrum, the resistance and the fulcrum being at the two extremities.

We likewise divide a lever into the arm of the power and that of the resistance. The first comprehends the portion of the lever which extends from the fulcrum to the power; the second is the portion included between the fulcrum and the resistance. When, in a lever of the first kind, the fulcrum occupies exactly the middle of the lever, we then say, that the lever has equal arms; when the fulcrum, is nearer either the power or the resistance, we then say, it has unequal arms.

The length of the arms of the lever gives more or less advan tage either to the power or to the resistance. If the arm of the power, for example, be longer than that of the arm of resistance, the increased advantage to the arm of power will be in proportion to its greater length. So that if the first of these arms be double or triple the second, it will be sufficient, if the power be one half or one third the resistance, to bring these two forces into a state of equilibrium.

In a lever of the second kind, the arm of the power is necessarily longer than that of the resistance, inasmuch as the fulcrum is at one extremity and the power at the other. This kind of lever is always advantageous to the power. The reverse is the case in a lever of the third kind, as then the power is between the fulcrum and the resistance.

A lever of the first kind is most favourable to an equilibrium, that of the second to overcome resistance, and a lever of the third kind conduces most to rapidity and extent of motion.

It is important to remark the direction in which the power is applied to a lever. The effect of the power is so much the more considerable, as the direction approaches nearer to a perpendicular to that of the lever. When this is the case, the whole force is employed to overcome the resistance; but when the direction is oblique, one part of the force tends to bring the lever into a proper direction, and this portion of the power is lost by the resistance of the fulcrum.

Moving Power.

That general property of matter by which it remains in a state of motion or rest, when it is not acted upon by any foreign cause, is called its *vis inertia.*

The force which produces motion can only be measured by the quantity of motion produced. This is obtained by multiplying the mass by the velocity.

Velocity is acquired in two ways, viz. either by the continued action of a force, as in the gravity of bodies, or in consequence of a force which imparts instantaneously a given velocity.

From what has been said, it is easy to infer, that every effort exerted upon a loose body will impart motion. The direction of the motion, its velocity, and the space it will pass over, must depend upon the mass, the intervals of the action exerted upon it, and the forces which act upon it during its motion. Thus a body thrown from the hand acquires instantaneously a velocity proportioned to the intensity of the effort, and the mass of the projected body. The continued action of gravity modifies incessantly both the velocity and the direction of the motion, which also ceases when the body falls on the surface of the earth. The motion is also retarded by the resistance of the atmosphere, the effect of which increases with the velocity of the body, the extent of its surface which strikes against the air, and the specific gravity of the body.

Friction is the resistance which one body is obliged to overcome in gliding over another.

The force which unites two polished surfaces, when brought in accurate contact with each other, is called adhesion. This force is measured by the effort required to separate them, acting perpendicularly to the surfaces. The more polished the surfaces in contact, the greater will be the adhesion, and the less the friction; when we wish, therefore, two bodies to glide upon each other, we polish the surfaces, or interpose some liquid between them.

THE BONES.

The bones determine the general form and dimensions of the body. In consequence of their physical properties, they fulfil a very important use in the different positions and motions; they form the different levers, which the animal machine presents, and serve to transmit the weight of all the parts of our body to the earth. They are employed as levers of the first, second, and third kind. When they are *in equilibrio*, a lever of the first kind is almost always employed; if a considerable resistance is to be overcome, they represent a lever of the second kind; and in other movements, they are employed as levers of the third kind; which, as was before observed, though unfavourable to the action of the power, conduces very much to the rapidity and extent of the motions. The greater part of the projections and eminences of the bones serve to change the direction of the tendons, so that they may be inserted in a direction less distant from the perpendicular.

As means of transmitting weight, the bones represent hollow columns, which thus augment, very much, the general resistance of the skeleton and each bone.

Form of the Bones.

The bones are divided into *short*, *flat*, and *long*. The short bones are placed in those parts which are very solid, but have little mobility, as the feet, and the vertebral column. The flat bones chiefly compose the walls of the cavities; they concur also, advantageously, in the movements and attitudes, by the extent of surface which they present for the insertion of the muscles. The long bones are principally employed in locomotion, and are only found in the extremities. The form of their body, and that of their extremities, is particularly worthy of notice. The body is always the smallest part of the bones, and is generally rounded; but, on the contrary, they always grow larger at their extremities. This arrangement of the body of the bones, assists in giving form to the limbs, and the increased volume of the articulated extremities besides this use, gives solidity to the articulations, and diminishes the obliquity of the insertion of the tendons upon the bone.

The short bones are very spongy in their texture, by which they present a considerable surface, without much weight. The same remark applies to the extremities of the long bones, but their bodies are very compact and heavy, which impart to them a great power of resistance, which was necessary, because these parts have to sustain all the forces, which act upon these bones.

The spongy tissue of the short, and the extremities of the long bones are filled with a medullary fluid; the cavities of the long bones, are filled with a substance called *marrow*.

Articulations of the Bones.

They are distinguished into those which permit, and those which do not permit motion. The first presents subdivisions, founded upon the form of the articulating surfaces. The second are also founded on the disposition of the articulating surfaces, and the kind of motions, which these articulations permit.

In the moveable articulations, the bones are never in immediate contact. There is always interposed between them, an elastic substance, differently disposed, according to the articulation, and destined to support easily the strongest pressure, to weaken shocks, and facilitate motion. Sometimes this substance is homogeneous in its structure, adheres equally to the surfaces of both bones, and constitutes what has been called the *articulation of continuity;* it is then of a fibro-cartilaginous nature. Sometimes this substance is formed of a lamina on each articulating surface; this is what is called the *articulation of contiguity;* in this case the substance is cartilaginous.

It is said that the substance which covers the bone in this last kind of articulation, is formed of fibres arranged at the side of each other, in a direction perpendicular to the surfaces which they cover. This opinion appears to me, to merit further investigation. The cartilages are of a homogeneous lamina.

The articulations thus arranged are most favorable to a gliding motion; the surfaces in contact are highly polished, and a particular liquid, the *synovia,* is continually poured out between them. For the same reasons, the adhesion is very strong, which adds to the solidity of the articulation in contributing to prevent displacements.

In certain moveable articulations we find, between the articulated surfaces, loose fibro-cartilaginous substances. They have been supposed to act like cushions, yielding to pressure and afterwards returning to their natural form; thus protecting those surfaces with which they are in contact. For this reason, it is said, they are found in those joints which sustain the most considerable pressure. We think this opinion is not sufficiently proved. Indeed, they are not found in the hip, nor the ankle joints, which support, habitually, the greatest efforts. Do they not rather serve to favour extent of motion, and to prevent displacement?

About, and sometimes in the interior of joints, we find fibrous bodies, which are called ligaments, which perform the double office of keeping the bones in their respective situations, and limiting the movements which they execute one upon another.

Attitudes of Man.

We will now examine man in the different positions which he can assume; and, first, in that posture which is the most common to him; that is, upon his feet.

We see, in the first place, that the head, united intimately with the *atlas*, forms with it a lever of the first kind, the fulcrum of which is the articulation of the lateral masses of the atlas, while the power and the resistance occupy each an extremity of the lever, represented the one by the face, the other by the *occiput.* The fulcrum being nearer the occiput than the anterior part of the face, the head tends, by its own weight, to fall forwards; but it is retained in *equilibrio* by the contraction of the muscles which are attached to its posterior part. It is the vertebral column then which supports the head, and transmits the weight to its inferior extremity. The superior extremities, the soft parts of the neck, the thorax, and the greater part of the abdominal viscera, press, more or less directly, upon the vertebral column.

In consequence of the great weight of these parts, it was necessary that the vertebral column should possess great solidity. Indeed, the bodies of the vertebra, the intervertebral fibro-cartilages, and the ligaments which bind these parts together, form a column of great strength. When we reflect upon the structure of the vertebral column, that it consists of portions of erect cylinders placed one above another, that it forms a pyramid, the base of which rests upon the sacrum, and that it presents three curvatures in opposite directions, which cause its power of resistance to be sixteen times greater than if it possessed none; we can then form some idea of the great resistance of which it is capable. We know that it is not only capable of supporting the organs which press upon it, but also burdens of great weight.

The weight of the organs which the vertebral column sustains, causing it to incline forward, there are muscles placed along its posterior part which resist this tendency. Under these circumstances, each vertebra, and the parts of which it is composed, represent a lever of the first kind, of which the fulcrum is in the fibro-cartilage, which sustains the vertebra, the power in the muscles which draw it backward, and which are attached to the spinous and transverse processes, and the weight or resistance in those parts which draw it forward.

The vertebral column, as a whole, represents a lever of the third kind, of which the fulcrum is in the articulation of the fifth lumbar vertebra, with the *os sacrum.* In this case the weight, or resistance, is in those parts which tend to carry the column forward, and the power in the muscles which are placed on its posterior part. As the power acts principally at the inferior part of the lever, it is there that nature has placed the strongest muscles; it is there that the pyramid, represented by the vertebral column, has the greatest thickness, and that the apophyses of the vertebræ are more developed and more horizontal; it is also there that the sense of fatigue is first perceived, when we remain long in an erect position.

The muscular power will act efficiently in preserving the equilibrium, necessary in standing, in proportion as the spinous processes are longer, and nearer the horizontal direction.

The weight of the vertebral column, and of the parts which press upon it, is transmitted directly to the pelvis; which, resting upon the thigh bones, represents a lever of the first kind; the fulcrum of which is in the ilio-femoral articulations, the power and resistance are placed posteriorly and anteriorly. The pelvis partly sustains the weight of the abdominal viscera; the sacrum supports the vertebral column, and acting like a wedge, transmits equally to both of the thigh bones the weight, through the *ossa ilii.* The pelvis is in equilibrio upon the two heads of the thigh bones; this equilibrium results from a great number of combined efforts.

On one side, the abdominal viscera, pressing upon the pelvis, incline it forward, tending to depress the pubis; but the vertebral column by its weight, acts in an opposite direction.

The weight of the vertebral column being much greater than that of the abdominal viscera, it would appear necessary to establish the equilibrium, that powerful muscles, passing from the thigh bones, should attach themselves to the pubis, and, by their contraction, counterbalance the excessive weight of the vertebral column. Such muscles, in fact, exist, but it is not the use of these muscles to preserve the equilibrium of the pelvis upon the thigh bones; for the pelvis, so far from having a tendency posteriorly, rather inclines anteriorly, because the muscles which resist the tendency of the vertebral column to incline forward, having the pelvis for their fixed point, have a considerable tendency to carry it upward. There are again those muscles which move the thigh bones, on the posterior part of the pelvis, which prevent its being elevated, and which are the principal agents, in preserving the equilibrium of the pelvis upon the thigh bones: nature has formed these muscles numerous and very powerful.

The articulations of the thigh bones with the *ossa-ilii* are much nearer to the pubis than to the sacrum; from which it happens that the posterior muscles act upon the longest arm of the lever, which is favourable to their action.

In the erect posture of the body, the thigh bones transmit directly to the tibiæ, the weight of the trunk. They fulfil easily this use from the strength of their articulation with the *ossa-ilii*.

Besides the uses which the neck of the thigh bones perform in the various motions of the body, they are likewise useful in standing. As their head is directed inwards and upwards, they not only support the vertical pressure of the pelvis, but they have a tendency to prevent the separation of the *ossa-ilii*, thus counteracting the opposite action of the sacrum.

The thigh bones transmit the weight of the body to the tibiæ; but, from the manner that the pelvis presses upon their inferior extremities, they have an inclination forward; while the contrary is the case at their superior extremities. In order to preserve their equilibrium upon the tibiæ, it is necessary, therefore, that there should be powerful muscles to oppose this tendency. The muscles by which this is effected, are the rectus, and *triceps femoris*,* the action of which is favoured by the rotula, placed behind their tendon. The posterior muscles of the leg, which are attached to the condyles of the femur, concur also in preserving the equilibrium.

The tibiæ transmit the weight of the body to the feet, without any assistance from the fibulæ. But, in order that the first of these bones may fulfil, conveniently, this office, it becomes necessary that the muscles should oppose the disposition which exists at their superior extremities, to be carried forward. The gastrocnemii muscles fulfil this office, in part, but all the muscles situated on the posterior part of the leg concur.

* The author probably refers to the cruralis and vasti muscles.—*Trans.*

The feet sustain the whole weight of the body, for which their form and structure render them admirably suited. The sole of the foot is very extensive, by which the firmness of the erect position is secured. The skin and epidermis of this part are very thick. Beneath the skin is a lamina of fat of considerable thickness at those places where the foot presses upon the earth. This fat forms an elastic cushion, which diminishes the effect of the pressure produced by the weight of the body. The whole inferior surface of the foot does not touch the ground. The heel, the external edge of the foot, the part which corresponds to the anterior extremity of the metatarsal bones, and the extremities or balls of the toes, are the points which generally press upon the earth, and transmit the weight of the body. We also find at each of these points, fatty masses, of considerable size, which are evidently intended to prevent inconvenience from too great pressure; that which is placed immediately beneath the head of the os calcis is very remarkable; it is attached by its superior face to the bone, but is distinct from the rest of the fatty substance which adheres to the heel. The other fatty masses, or cushions, are less voluminous, but are arranged in a manner completely analogous.

The tibia transmits the weight of the body to the astragalus, from which it is again imparted to the rest of the bones of the foot; the os calcis receives the greatest portion, and the remainder is divided between the other points of the foot which press upon the ground.

The following is the general mode by which this is effected. The weight that the astragalus sustains is transmitted; 1st, to the os calcis; 2nd, to the scaphoides. The os calcis, being placed immediately beneath the astragalus, receives the greater part of its pressure which it transmits partly to the ground, and in part to the os-cuboides. This last and the os-scaphoides, through the medium of the cuneiform bones, press in their turn upon the metatarsal bones, which transmit to the ground nearly all the pressure they receive; the surplus is propagated to the toes. This mode of transmission supposes the foot to touch the ground through the whole extent of the sole.

As the pressure of the tibia is felt over all the internal part of the foot, it has a tendency to press it outwards; the fibula is destined to counteract this when we stand in an erect position.

We have already seen that the muscles which prevent the head from falling forwards, arise from the neck; that those which fulfil the the same office to the vertebral column, arise from the pelvis; that those which preserve the pelvis in equilibro, are attached to the bones of the thighs and legs; that those which prevent the rotation of the thigh bones backward, are inserted into the tibia; and lastly, that those which retain the bones of the tibia in their vertical position, have their fixed point in the feet. It is then in the feet, that all the efforts required in standing, are at last concentrated; it is necessary, therefore, that the feet should present a resistance proportionate to the efforts which they are destined to support. But the feet have not any other means of resistance than what arises from their weight; all the rest which they exhibit is communicated by the weight of the body which they support; so that the same cause which tends to produce a prostration of the body, is also that which secures to it firmness in the erect position.

The space between the feet, as well as the surface which they cover, forms the base of support to the body. The state of equilibrium in the erect posture, is a vertical line passing through the centre of gravity, and falling upon some point included within the base of support. The position will be firm in proportion to the extent of this base; in this respect, the size of the feet is far from being an indifferent circumstance.

We know from observation, that this posture of the body is most secure, when the two feet are placed parallel to each other, and separated by a space equal to the length of one of them. If we enlarge, laterally, the base of support, by separating the feet, the posture becomes more secure in that direction, but we lose our firmness anteriorly and posteriorly. It is the reverse when we place one foot before and the other behind.

The more the base of support is diminished, the less secure is the posture, and the greater the muscular power required to preserve it. This happens when we endeavour to elevate ourselves on our toes. In this case the feet only touch the ground in the space comprehended between the anterior extremity of the metatarsal bones, and the extremities of the toes. This posture is very fatiguing and cannot long be endured. Some persons, dancers for example, can elevate themselves upon the extremities of their toes; a thing which is extremely difficult. Besides, whatever may be the part of the foot which touches the ground, it is always comprised in the four parts which we have mentioned at the commencement of this article, and we cannot mistake therefore, the uses of the fatty masses which are found there.

The position will also become very difficult, if not impossible, when the feet rest upon a very narrow plane; a tight rope for example. We may generally remark, that whatever contracts the base of support, proportionally diminishes the firmness of the posture; this any one may satisfy himself of, by observing those individuals who have accidentally lost their toes by frost; or the anterior part of the foot by a partial amputation; those who have one leg of wood, or persons walking upon stilts. In this last case the position is rendered still more difficult by the distance of the centre of gravity from the base of support.

The position upon both feet may be varied infinitely. The trunk may be inclined before or behind, or latterally; and the inferior extremities be bent in different ways. Those who understand all that has been said of the erect posture, will find no difficulty in explaining the attitudes here referred to.

Standing upon One Foot.

We sometimes stand on one foot; this attitude is necessarily fatiguing. It requires of the muscles which surround the hip joint, a strong and continued action, by which the equilibrium of the pelvis upon one thigh is preserved. As the body, and of consequence the pelvis, is inclined to fall to that side on which the leg is not applied to the ground, there is required of the glutœus maximus, medius, minimus; tensor vaginæ femoris, gemini, pyramidalis, obturatores, and the quadratus femoris, such a contraction, as will support the trunk. We may speak here of the use of the neck of the thigh bone, and of the projection of the great trochanter. It is evident that they render much less oblique the insertion of the muscles which have been before spoken of, and thus prevent so great a loss of power as would otherwise be the case.

It is scarcely necessary, to add, that in standing upon one foot, the base of support is only represented by the surface of the ground covered by the foot, and that it must, therefore, be necessarily less secure than when we stand upon both feet, whatever may be the posture. It will become still more difficult and tottering, if instead of applying the whole surface of the foot to the ground, we rest upon one point of it. It is quite impossible to preserve this position longer than for a few instants.

Kneeling.

The base of support in this posture appears at first sight to be very large; and as the centre of gravity is brought near the earth, one might suppose that it would be more secure even than standing upon both feet. But the size of the base which sustains the weight of the body, is far from being measured by the whole surface of both legs which touch the ground. The patella is nearly the only part which transmits the weight of the body to the ground. The skin also, which covers this part, is strongly pressed, and not being covered with a fatty cushion as we see on the feet, it soon becomes injured, if this position be long continued. For this reason we are in the habit of placing cushions under the knees, when we intend to kneel for any considerable length of time, by which we transmit the weight of the body to the ground through an intermediate substance which increases the base of support, and thus diminishes the effect of pressure. It is for a similar reason, that is to increase the extent of the pressure caused by the weight of the body, that we bend the thighs backwards, and throw the weight upon the legs and heels. This situation is much more solid and less fatiguing, because the base of support is much enlarged, and the centre of gravity nearer the ground.

Attitude of Sitting.

We may sit in different ways; on the ground, for example, with the legs extended; on a low seat, the feet touching the ground, or upon an elevated seat, in which the feet do not touch the ground but are suspended, and the back supported, or unsupported.

In all the positions where the back is not supported, nor the feet touching, the weight of the body is transmitted to the ground by the pelvis, the size of which at its lower part is greater in man than in any other animal. The base of support by the trunk becomes distinct from that of the bones of the inferior extremities; it is represented by the extent which the parts occupy on the resisting plane which sustains them. The more voluminous and fat they are, the more solid will be the attitude of sitting.

When, in the posture of sitting, the back is not supported, it requires the permanent contraction of the posterior muscles of the trunk, to prevent its falling forward. The position is on this account fatiguing, as we observe after sitting on a stool for some time, but which is not the case when the back is supported, as in sitting on a sofa. Then the muscles which support the head, alone act and are the only ones fatigued. High chairs are intended to prevent this inconvenience, as they sustain the back and head. Whatever be the manner of sitting, we can preserve this attitude for a long time. 1st. Because it requires the action of but few muscles. 2d. Because the base of support is large, and the centre of gravity near the earth. 3d. Because the nates, in consequence of the thickness of the skin, and the quantity of fat, can support a strong and long continued pressure without inconvenience.

Of the Recumbent Posture.

This is the only position of the body which does not require any muscular effort. This is the attitude of repose, and of those whose muscular powers are prostrated by disease. We can also endure this attitude for a long time. The only organ affected by this position, is the skin, which corresponds to the base of support. The pressure of the weight of the body, though very much divided, soon causes a sense of uneasiness, and afterwards of pain; and, if the position remains long the same, as we find in some diseases, the skin becomes ulcerated, and sometimes gangrenous, particularly at those points which have the greatest pressure, as the posterior surface of the pelvis, the great trochanters, &c. It is to avoid this inconvenience that we endeavour to procure beds which are soft, and the elasticity of which permits a more equal division of the pressure upon all those points of the skin which correspond to the base of support.

Of Motions.

There are two kinds of motions; the end of the first is to change the relative situation of the different parts of the body. That of the second, to change the situation of the whole body upon the surface of the earth. The one is called *partial*, and the other *locomotion*.

Of Partial Motions.

The greater number of partial motions make an inherent part of the different functions. Many have already been described, and the others will be in their turn. We shall only treat here of those which may be insulated in the history of the functions. We shall successively treat of those of the face, head, trunk, and superior and inferior extremities.

Partial Motions of the Face.

It is easy to perceive that these motions have two distinct ends. The first is to concur in the sensation of seeing, smelling and tasting; also, the receiving of aliments, mastication, deglutition, voice and speech. The second indicates the operations of the intellect, and the passions.

Independently of those motions of the face which concur in vision, smelling, tasting, voice and speech, of which we have already spoken, and of those which serve to receive the food, for mastication, and deglutition, &c. of which we shall speak in their proper place; the muscles of the face cause in this part motions, which serve to express certain intellectual acts, different dispositions of the mind, and instinctive desires and passions. Pleasure and pain, joy and sadness, desire and fear, anger, hatred, love, &c. have each an expression in the face which characterises them. The painful and gloomy affections, and violent desires are generally accompanied with a contraction of the countenance. The eye-brows are contracted into a frown, and the angles of the mouth drawn backwards and downwards; on the contrary, during the existence of the mild and amiable affections, gaiety, agreeable sensations, and satisfied desires, the form of the face is expanded, the eye-brows elevated, the eye-lids separated, and the angles of the mouth drawn upwards and backwards, which produces smiling. It is found that persons in whom the different expressions are the most strongly marked, or as it is commonly expressed, whose *physiognomy* is the most remarkable, are usually distinguished for the vivacity of their character.

It is generally the reverse with persons whose countenances are without expression. When any particular disposition of the mind, or passion, is long indulged in, the muscles which are habitually contracted to express it, acquire a manifest superiority in volume over the other muscles of the face. The physiognomy therefore preserves the expression of the passion, even when it is not perceived, or a long time after it has ceased, and is generally a correct index of the character and habitual passions of the individual.

The colour of the skin of the face is also a powerful means of expressing the intelligence and passions. We shall treat of this subject under the article *capillary circulation.*

Motions of the Head upon the Vertebral Column.

The head may be inclined anteriorly, posteriorly, or laterally; it may also execute a rotary motion, either to the right or to the left. The motions by which the head is inclined forwards or backwards, or sideways, if they are not extensive, take place in the articulation of the head with the first cervical vertebra, but if the extent of motion is considerable, all the vertebræ of the neck take a part in it. The rotary motions are essentially executed in the articulation of the atlas, with the dentatus which is evidently intended for this purpose. These different movements, which are frequently combined together, are performed by the successive, or simultaneous contraction of the muscles which extend from the chest and neck towards the head.

It is easy to see that the movements of the head favour vision, hearing and smelling; they are also useful in the production of the different tones of the voice, by permitting the elongation or shortening of the trachea, the vocal tube, &c. These movements serve also, as a means of expressing some of the operations of the mind, as approbation, consent, refusal, &c. which are indicated by certain motions of the head upon the neck; some passions also induce certain movements or particular attitudes of the head.

Movements of the Trunk.

We shall only speak in this article of particular movements of the vertebral column; those which are peculiar to the thorax, the abdomen and the pelvis will be exposed hereafter.

Flexion, extension, lateral inclination, circumduction, and roation, are the motions executed by the vertebral column, as a whole; these are also executed by each region, and even by each particular vertebra. These different motions take place in the intervertebral fibro-cartilages; they are, likewise, more easy and more extensive, as these fibro-cartilages are thicker and larger. For this reason, the motions of the cervical, and lumbar portions of the vertebral column, are evidently more free and more considerable than those of the dorsal portion. It is well known that the cervical fibro-cartilages, and especially the lumbar, are proportionally thicker than the dorsal.

In the motions of flexion, either anteriorly, posteriorly, or laterally, the fibro-cartilages are pressed down in the direction towards which the flexion is made; of course then, that part which is thickest will be pressed down the most; this is one of the reasons why flexion anteriorly is much more extensive in the vertebral column than in any other direction.

In rotation, all the intervertebral bodies must undergo a lengthening of the plates which compose them. The centre of the bodies of which we are now speaking, is soft and almost fluid; the circumference only, offers a considerable resistance to those motions in which the vertebræ are made to approach each other, but this circumference yields sufficiently to form a sort of pad between the two bones. The disposition of the articulating *facettes* of the vertebræ, is one of the circumstances which have most influence upon the extent, and mode, of the reciprocal motions of the vertebræ.

When we consider the motions of the vertebral column as a whole, it represents a lever of the third kind, the fulcrum of which is in the articulation of the fifth lumbar vertebra with the sacrum; the power is in the muscles which are attached to the vertebræ; and the resistance in the weight of the head, the soft parts of the neck, chest, and part of the abdomen. Each vertebra, on the other hand, taken separately, represents a lever of the first kind, the fulcrum of which is in the middle, upon the vertebra placed directly underneath, the power is posterior, and the resistance anterior, or the one to the right hand, the other to the left, towards the extremities of the transverse processes.

The motions of the vertebral column are frequently accompanied with those of the pelvis upon the thigh bones, they then appear to have an extent of motion far greater than they actually possess.

The motions of the vertebral column are often useful in assisting those of the superior and inferior extremities, and of rendering less fatiguing the different attitudes which the body assumes as a whole.

Motions of the Superior Extremities.

The superior extremities being the principal agents by which we effect, directly or indirectly, those changes in surrounding bodies that we desire, therefore, require extreme mobility to be united with a sufficient degree of solidity. We find in these members many long bones, several of which are of considerable length, and slender; the short bones are small; and both of them are light; the articulating surfaces are of small dimensions; the muscles are numerous, and their fibres very long. The bones almost always represent levers of the third kind; which are favourable, as has been before remarked, to extent and rapidity of motion. When we consider the motions of the superior extremities as a whole, in relation to the trunk, or those of the different parts as they respect each other, we readily perceive that they unite in a very eminent degree, great extent, rapidity, and variety of motion. The solidity of these members is not less worthy of remark. In numerous situations, they have to support considerable efforts, as when we support ourselves upon a cane, or when we fall forwards, and the hands receive the whole shock of the fall, &c.

It is impossible for us to enter into all the details of this wonderful piece of mechanism. We refer the reader, on this point, to "L'Anatomie Descriptive" of Bichat, whose genius exerted itself with great success in explaining the mechanism of animals.

The superior extremities are essentially useful in exercising the sense of touch, of which the hand is the principal organ. They assist us also in exercising the other senses, they aid us in bringing objects near, or in carrying them to a distance, or in placing them under circumstances favourable to the action of the senses. Their motions concur powerfully in expressing certain intellectual and instinctive acts. The gestures form a true language, which is susceptible of acquiring great perfection, and which may become of the greatest utility, as happens in the deaf and dumb. In these cases, the gestures not only paint the sentiments, wants, and passions, but they also express the slightest shades in the faculty of thought.

The superior extremities are often useful in the different attitudes of the body. In some cases, they transmit to the earth a part of its weight, enlarging, of course, the base of support. This is done when we rest upon a cane, or when, being upon our knees, we place the hands upon the ground; or, when in sitting upon a horizontal plane, we lean upon one or both of our elbows, &c. They also increase the security of the posture of standing erect, when we carry them in a direction opposite to what the body is inclined to fall by its own weight. We see every hour that they are useful in different modes of progression.

Movements of the Inferior Extremities.

Although there is a manifest analogy between the structure of the superior and inferior extremities, it is, nevertheless, evident in the last, that nature has attended much more to their solidity and extent of motion, than to their rapidity and variety. This was necessary, for it is rare that these members move without supporting the weight of the body; they are the principal agents in locomotion.

When we impress certain modifications upon foreign bodies by the inferior extremities, they move independently of the trunk. Thus, when we change the form of a body, by pressing upon it with the foot, or when we displace it with a blow of this part, or when we exercise the sense of touch with the foot, to judge, for example, of the resistance of the ground on which we intend to walk, &c. it is plain that these different motions do not drag the trunk after them.

We shall not describe here, particularly, the different general or partial motions which the members can effect; we shall only speak briefly of the different modes of locomotion, that is, of those motions by which the body is transported from one place to another, which are, walking, running, leaping, and swimming.

Locomotion.

Of Walking.—The action of walking is not always executed in the same manner. We may walk forwards, or backwards, or sideways, or in any intermediate direction, we may walk upon an ascending or descending plane, and upon a solid or moveable body; walking also differs according to the extent and quickness ot the steps, &c. Whatever may be the mode of walking, it is necessarily composed of a succession of steps; so that the description of walking only relates to the manner in which a series of steps are taken. It is only necessary, therefore, to inquire into the manner in which the art of stepping, with its various modifications, are performed.

Suppose a man, then standing in an erect position, with both feet at the side of each other, and about to walk on a horizontal plane, at a common pace both in extent and quickness. It will be necessary to bend one of the thighs upon the pelvis, in order to raise the foot from the ground, by a general shortening of the limb. The flexion of the thigh throws forward the whole limb; the foot is then applied to the ground, the heel touches first, and afterwards the whole inferior surface of the foot. When this motion is effected, the pelvis rolls forward upon the head of the thigh bone, which is immoveable. This rotation of the pelvis upon the head of the femur, has for its object, 1st, to carry forward the whole of the member which was raised from the ground; 2d, also to carry forward the side of the body corresponding to the limb which is moved, while the side corresponding to the unmoved limb remains behind. These two effects are hardly perceptible when the steps are very short; they are remarkable in a common walk, but are much more so when we take long steps. Thus far there has been no progression, the base of support is only modified; in order that the step may be completed, it is necessary that the member remaining behind should be moved up, either in the same line, or beyond that which was first moved. For this purpose, the foot which is behind is detached from the ground, successively from the heel towards the toe, by a rotary motion, of which the centre is in the articulation of the bones of the metatarsus with the phalanges of the toes, so that at the end of this motion the foot no longer touches the ground at its posterior extremity. From this movement of the foot there is an elongation of the limb, the effect of which is to carry the corresponding side of the trunk forward, and to determine the rotation of the pelvis upon the head of the femur of the limb first moved. This motion being executed, the limb becomes flexed, the knee is thrown forward, and the foot detached from the ground, afterwards the whole limb describes the same motions which had been before executed by the limb of the opposite side.

By this succession of motions of the inferior extremities, and of the trunk, walking is executed, during which we see that the heads of the thigh bones, are by turns fixed points, on which the pelvis turns as on a point, describing arcs of circles proportioned to the extent of the steps.

In order that we may walk in a right line, it is necessary that the arcs of circles described by the pelvis, and the extension of the lower limbs, when they are carried forwards, should be equal; without this we shall deviate from a right line, and the body will be directed towards the side opposite to the limb, the motions of which are the most extensive. As it is difficult to make the two limbs execute successively, exactly the same extent of motion, there is always a tendency to deviate from a straight line, which would constantly occur, if this deviation was not corrected by the sight. Any person may easily convince themselves of this, by walking some distance with the eyes closed.

Having exposed the mechanism of walking forwards, it will be no very difficult task to explain walking backwards or sideways.

In walking backwards, one of the thighs is bent upon the pelvis, at the same time the leg is bent upon the thigh, the extension of the thigh upon the pelvis succeeds, and the whole of the limb is carried backwards. Afterwards the leg is extended upon the thigh, the anterior part of the foot touches the ground, and immediately afterwards the whole of its inferior surface. At the moment that the foot directed backwards is applied to the ground, that which remains before is raised upon its toe, and the corresponding member elongated; the pelvis is thrown backwards, making a rotation upon the head of the thigh bone, which is directed backwards. The limb which is before, is entirely raised from the ground, and carried backwards, in order to furnish a fixed point for a new rotation of the pelvis, which will be executed in its turn by the opposite member.

When we wish to execute a lateral motion, we bend slightly one of the thighs upon the pelvis, in order to raise the foot from the ground; then throw the extremity into a state of abduction, and apply the foot to the ground, and immediately afterwards we draw up the other limb towards the one which had been displaced; and so on.

When we walk upon an ascending plane, we know that it produces great fatigue. In this mode of progression, the flexion of the limb carried first forward must be considerable, and the extremity remaining behind must not only execute the motion of rotation upon the pelvis, but it is necessary that it should raise the whole weight of the body, in order to transport it to the member which is before. The anterior muscles of the thigh carried forward, are the principal agents in the transportation of heavy bodies; these muscles are also very much fatigued in the action of passing up a ladder, or any other ascending plane.

For opposite reasons, walking upon a descending plane is more fatiguing than upon a horizontal plane. Here the posterior muscles of the trunk must act with force, to prevent the body from falling forward.

All the modes of progression which we execute rapidly, require easy movements in all the articulations of the inferior extremities, and an equal action of every part of the limbs; the least imperfection in the articulating surfaces, or their mode of gliding upon each other, the least difference in the length, or form, of the extremities, or the contractile force of the muscles, unavoidably cause sensible alterations in the progression, and render it more or less difficult.

Of Leaping.

If we examine with attention the action that we are now about to investigate, we shall perceive, that during this motion, the body becomes a projectile, and that it is governed by all the laws peculiar to them.

A leap may take place either perpendicularly, anteriorly, posteriorly, or laterally, &c. We must in all these cases consider all the circumstances which accompany it. Every kind of leaping must necessarily be preceded by a flexion of one or more of the articulations of the trunk and inferior extremities; the sudden extension of these flexed articulations is the particular cause of the leap.

Suppose the leap to be made vertically, which is the most common; the head is bent upon the neck, the vertebral column is curved anteriorly, the pelvis is bent upon the thigh, the thigh upon the leg, and this again upon the foot, and the heel either touches the ground lightly, or not at all. This state of general flexion is suddenly succeeded by a universal extension of the flexed articulations; the different parts of the body are rapidly elevated with a force which surpasses its weight, in a variable degree. Thus the head and chest are directed superiorly by the extension and retraction of the vertebral column; the trunk, as a whole, is affected in the same way by the extension of the pelvis upon the thigh bones; the thighs being raised suddenly, act upon the pelvis, and the legs in their turn act upon the thighs. From all these united efforts, there results a projectile power, by which the body is raised from the ground, and the elevation will be in the proportion of the superiority of the power to the weight; after which it falls to the ground, presenting the same phenomena as all other bodies, which are operated upon by the attraction of gravitation.

In the general retraction by which the leap is produced, the muscular contraction does not take place equally in every part. It is plain that it must be the greatest where the weight to be raised is the most considerable. This is the reason why the muscles which extend the leg upon the foot, are those which act with the most energy, inasmuch as they raise the whole weight of the body, and give to it an impulse which surpasses its resistance. These muscles are admirably arranged for this purpose. They are extremely powerful, and are inserted perpendicularly to the lever which they are to move, the os-calcis, and act by the arm of a lever which has considerable length.

It is proper to remark, that the vertical leap does not result from any direct impulse, but it is a mean between opposite impulses, which the trunk and inferior extremities impart at the instant of the leap. Indeed the retraction of the head, the vertebral column, and the pelvis, have rather a tendency to throw the trunk posteriorly, than superiorly; the rotation of the thigh bones upon the tibiæ, on the contrary, carry the trunk rather anteriorly, than superiorly; the motion of the leg again has a tendency to throw the trunk superiorly, and posteriorly. When the result of the exertion is a vertical leap, the forces which carry the body forwards and backwards, destroy each other, and those which throw the body upwards, alone take effect.

When the leap takes place anteriorily, the rotation of the thigh predominates over the impulses posteriorly; when the leap is made backwards, it is the motion of extension in the vertebral column, and of the tibia upon the foot, which produce the effect.

The length of the bones of the inferior extremities is advantageous for extending the leap. We pass over the greatest possible distance in leaping forwards; this is attributable to the length of the thigh bone. Sometimes we precede the leap by running a short distance forward; the impulse which the body thus acquires is added to that which it receives at the moment of the leap, by which its extent is increased.

The arms are not entirely useless in leaping. They are brought towards the body at the moment when the flexion of the different articulations is made, preparatory to the act of leaping. They are thrown out, on the contrary, at the moment when the body leaves the ground. The resistance which they present to the muscles which elevate them, enables the muscles to exert some force in throwing the trunk upwards, and thus to concur in the act of leaping.

The arms fulfil this purpose more effectually when they present a firm resistance to the contraction of the muscles which elevate them. The ancients having made this remark carried in each hand weights, called *halteres*, when they wished to exert themselves in leaping; by properly adjusting the arms, we can favour a horizontal leap, thus giving to the superior part of the body, an impulse backwards or forwards.

We are capable of leaping with one foot, or, as we commonly express it, *hopping*. But this mode of leaping must be necessarily less extensive than when the effort is made simultaneously by both limbs. Sometimes we leap with both feet in contact and parallel to each other; sometimes one foot is carried forwards during the projection of the body; in this case one foot receives the weight of the body at the moment it touches the ground.

No impulse will be communicated to the body, by the plane which sustains it, at the moment of leaping, unless it be elastic, and combines its reaction with the effort of the muscles. In general, the ground serves no other purpose than that of resisting the pressure exerted by the feet. Every person knows that it is almost impossible to leap, when the ground is soft and yields to the pressure of the feet.

The merit of discovering the true theory of leaping is due to the celebrated Barthez, of Montpelier. Until his time, the most incorrect ideas were entertained of this phenomenon. There is some analogy between the action of an elastic curve, and that of the body in leaping.

Of Running.

Running is a combination of walking and leaping; or rather it consists of a succession of leaps, executed alternately by each limb, while the other is carried forwards or backwards, to be applied to the ground, and to produce the leap as soon as the first has had time to be carried backwards or forwards, accordingly as we run in one or the other direction. We may run with more or less rapidity, but there is always a moment when the body is suspended, in consequence of the impulse communicated to it by the limb which remains behind when we run forwards. This constitutes the difference between running and walking fast, in which the foot carried forward, touches the ground, before that which is behind leaves it.

For the same reasons, which we have given under the article *walking*, running is least fatiguing upon a horizontal plane. When it is executed upon an ascending or descending plane, it is always more or less laborious, and cannot be continued long.

We shall not even briefly describe the numerous modifications in the progressive motions of man, such as climbing, walking, with crutches, stilts, and artificial limbs; or of the different motions either in common dancing, or upon a tight or slack rope; or those which are executed by tumblers, fencers, and riders, &c.

Considerations of this kind are important, but they can only compose a part of a complete treatise upon animal mechanics; a work which still remains to be executed, notwithstanding what has been done by Borelli and Barthez on this subject. We shall only say a few words of swimming.

Of Swimming.

The body of man is specifically heavier than water, of consequence, when left in the midst of a considerable mass of this fluid, he will sink to the bottom; this will take place with so much the more facility, as the surface which strikes the water is of small extent. If, for example, the body is placed vertically, the feet below and the head above, it will sink much more rapidly, than if the body was placed horizontally on the surface of the fluid. Some individuals, however, possess the faculty of rendering themselves specifically lighter than the water, and, of consequence, of resting without any effort upon its surface. This is effected by filling the chest with a large quantity of air, the specific gravity of which, being much less than the water, counter-balances the tendency which there is in the body to fall to the bottom.

It is not, however, by this practice, that swimmers are enabled to move along the surface of the water, but by the motions which they execute with their limbs. The object of the motions executed by the swimmer, is to sustain the body on the surface of the water, or to direct its progression. Whatever may be the intention of the swimmer, he must act upon the water in such a manner, that it shall present a sufficient resistance to support his body. According to this view, he acts upon the water by pressing suddenly upon it, before it has time to escape, acting rapidly upon a great number of points by the action of his hands and feet, the resistance being in proportion to the mass of water displaced. The motions of the inferior extremities in the common manner of swimming are very analogous to those which they execute in leaping. There are various modes of swimming, but in all, it is necessary to strike or press the water rapidly before it can be displaced.

It is impossible for a man to fly; his specific gravity, when compared with the atmosphere, and the force exerted by the contraction of his muscles, is infinitely too weak. All the attempts heretofore made with this intention, by machines formed in imitation of the wings of birds, have been equally unsuccessful.

Of the Attitudes and Motions in different Ages.

From the embryo state, to the eighteenth or twentieth year, the bones are continually changing their form, volume, &c. Of course, during all the time that the bones are altering their form, the attitudes and motions must exhibit changes analogous to those which take place in the skeleton. We have already seen that the muscles, and the muscular contraction are very much modified by age; these circumstances have all an influence upon the motions. Ordinarily, by the twentieth, to the twenty-second year, the increase of the long bones is terminated, but they continue to increase in thickness until the adult age is completed, after which all increase ceases, and the changes which then take place in the bones, even to the most advanced old age, only relate to the nutrition of these organs, and their chemical composition.

Attitudes of the Fœtus.—The situation of the fœtus in utero, depends on circumstances but imperfectly understood. For the most part, its head is directed below; this arises probably from its weight, but why the occiput corresponds almost always to that part of the pelvis which is above the acetabulum, or why it sometimes happens that the breech is found below, we are entirely ignorant.

The thighs in the fœtus are bent upon the abdomen, and the legs upon the thighs, the arms are crossed on the anterior part of the trunk, and the head inclined upon the breast, so that it occupies the least possible space. This does not depend upon muscular contraction, it is the effect of the tendency in the muscles to relax themselves; at a more advanced age, we often take this position, when we wish to put all the muscles in a state of repose

At the end of four months, the child begins to execute partial motions, and perhaps some slight motions, which displace the body wholly. These motions are irregular, arising at various periods, and continue until the end of pregnancy, and are frequently exerted by the inferior extremities, as can be distinguished at those points where they are felt. We cannot suppose that they depend upon the will, no intelligence at the time existing; this is also evident from the fact, that acephalous infants, that is, those which have no brain, exhibit these motions the same as the most perfectly formed children.

The new born infant is incapable of assuming any particular position, but passively preserves that which is given to it; we however perceive that lying upon its back is the most agreeable; and is, no doubt, most favourable to the feeble state of its muscular system. The extremities move with facility; but its physiognomy is without expression. At the end of two or three months, it changes its position of its own accord. It lays on its side or face, turns its head, and the motions of its limbs become more various and powerful. It seizes objects with more strength when they are presented to it, and carries them to its mouth. When it sucks, it compresses with force the breast of its nurse, &c. but it remains long incapable of supporting itself upon its feet, or even of sitting. The following are the reasons of this; the head, being proportionally large and heavy, and not supported by any adequate muscular effort, falls forward; the weight of the viscera of the chest, and especially of the belly, is proportionally great; the vertebral column presents but one curve, the convexity of which is behind. The posterior muscles of the trunk are too weak to resist the disposition in the vertebral column to fall forwards; besides, the spinous processes not being developed, the arms of the lever by which they act are very short, a circumstance most unfavourable to their action. The pelvis is very small, and, being very much inclined forwards, does not support the weight of the abdominal viscera. The inferior extremities are but little developed, and are too weak to sustain the weight of the trunk, every kind of progression is therefore impracticable.

Soon, however, the infant, by using both its superior and inferior extremities at the same time, is able to transport itself over short spaces. From this circumstance, the extravagant idea has been advanced, that man is naturally a quadruped, and that standing upon two feet is the result of living in a state of society. If there were any foundation for this idea, these organs in the adult would resemble those of the infant, which, as we have before seen, is not the case.

Towards the end of the first year, or at the commencement of the second, in consequence of the developement of the bones, muscles, &c. and of the alteration in the proportional volume of the head and abdominal viscera, the infant becomes able to stand, but is still unable to walk, it soon acquires this power by taking hold of objects which are near it. At last, however, he walks alone, though his gait is tottering and uncertain, the body losing its balance by the slightest force. Walking is the first kind of locomotion which he is able to exert; it is generally a long time before he is able to run, or to make even inconsiderable leaps; but as soon as the different progressive motions become more firm and steady, he is in continual motion; he acquires agility and address, and a taste for the various sports of children, which almost always, especially in boys, serve to exercise the organs of locomotion and intelligence.

In a physiological point of view, the sports of children are well worthy of notice. When they are examined with attention, they will be found to mimic the actions of manhood. We may also remark the same feature in the sports of the young in other animals, which are generally imitations of those actions which their instinct will afterwards impel them to repeat.

In the sports of infants, we must not confound those which are purely instinctive, with those which are dependent on imitation.

From youth until the adult age, and even beyond it, all the phenomena which relate to the attitudes and movements of the body are in perfection; but with the approach of old age, they undergo a remarkable alteration, which arises from a loss of power in the muscular contraction. The action of the muscles, at this period, is imperfect and tremulous, which is very apparent in the attitudes and motions. The old man, whether walking or standing, is bent forward; the pelvis is bent upon the thighs, these upon the legs, and the legs inclined forward upon the feet. This state of half flexion tends to weaken still more the power of the muscles, which have not sufficient energy to preserve the erect posture of the body. The old man endeavours to make up in some degree for these defects, by means of a cane, which enlarges the base of support, and transmits directly to the ground the weight of the superior parts of the body. In very advanced old age, the motions become extremely difficult, and sometimes entirely lost.

Relation of Sensations to the Attitudes and Motions.

The sensations and motions have a reciprocal and manifest influence upon each other. Vision contributes to the fixedness of the greater number of the attitudes of our body; by it we judge of our comparative position with surrounding objects. When we are deprived of this means of judging of our equilibrium, as when we are on the top of a high edifice, or upon other elevated places, where we are only surrounded by the air, the position of the body becomes uncertain, and sometimes we are totally unable to preserve it. The utility of vision is still more apparent when the base of support is very narrow. A rope dancer cannot preserve the erect posture, unless his sight be constantly occupied with the position which he wishes to preserve, so that the perpendicular which falls through the centre of gravity, may pass directly to the base of support. Whatever may be the attitude which we assume, it is very uncertain, unless we employ vision; this is sufficiently evident in the postures and attitudes of blind persons.

If sight be of great assistance in the different attitudes, with much more reason must it be useful in the various partial and locomotions. Indeed, distinct vision favours our motions; it is that which gives to them their requisite precision and rapidity; in almost every instance, it directs them. If we bandage the eyes of any active man, he instantly loses all his agility, his gait is timid and tottering, especially if he be in a place with which he is not familiar. All his motions have the same character. The same phenomena occur in blind persons, who are readily recognised by the slight movements they execute, especially those which are not familiar to them. The absence of vision induces an indisposition to motion; the use of this sense, on the other hand, excites our activity; every one must be conscious of an instinctive desire of touching those objects which he sees for the first time.

Gestures.—A consideration of the relations between vision and motion, leads us to observe; that those motions which are destined to express our intellectual and instinctive operations, which are included under the generic names of *gestures*, may be divided into those which arise from organization, and, of consequence, must exist in man, in whatever condition he is found, and those which arise from the social state, and become improved with it.

The first are destined to express our most simple wants and most vivid internal sensations, as joy, grief, and fear, &c. Thus, in the expressions of the animal passions, gestures are to the other motions, what the cry is to the voice. We observe them in those persons who are blind from their birth, in the idiot, and the savage, as well as man in a civilized state, enjoying every physical and moral advantage.

The second kind of gestures can only exist in a state of society, require vision and intelligence, and are not observed in those who are blind from their birth, or in idiots, savages, or in those individuals who have lived in an insulated state. They may be called *acquired* or *social gestures*, from their analogy with the acquired voice. It is extremely probable that, if we could restore sight to a person who had been blind from birth, we should enable him, at the same time, to acquire those particular gestures of which we are now speaking.

It may be said, the gestures of a person born blind are like the voice of a person born deaf. These two phenomena, under these two different circumstances, are made to supply each other's place. The deaf and dumb make a continual use of gestures, and carry this mode of communicating their thoughts to a wonderful degree of perfection. The voice, on the other hand, is the only means of expressing their thoughts, which are employed by the blind; from this arises their fondness for music, and conversation, and the peculiar accent which they give to their voice.

Hearing has some influence upon the motions. This sense often concurs with vision in directing, and particularly in measuring them; thus causing them to return, after equal intervals, and producing a certain number in a given time; as we observe in dancing and marching. It has been long remarked that motions executed by the sound of music, were less fatiguing than without it. This arises from the regularity with which the muscles contract and relax alternately, the period of repose being equal to that of action; it may also be remarked, that music excites us to motion.

The relations of smelling and tasting with the attitudes, are too unimportant to attract much attention. With respect to touch, it is so intimately connected with muscular contraction, that, without it, this sensation cannot take place, and it is easy to see that it is intimately connected with all the phenomena which depend upon muscular contraction.

The internal sensations have no less influence upon the different attitudes and motions of the body, than the external. Who cannot distinguish, by his gait and gravity, a man suffering pain, or any other vivid sensation? We can even determine, with considerable certainty, the particular seat of the painful affection, by the arrangement of the body or the kind of gestures which the patient employs. In a violent cholic, e. g. the chest is thrown forward upon the pelvis, and the hands pressed upon the belly; a violent pain in the side naturally induces us to incline to the side affected; and the stone in the bladder compels the patient frequently to assume a particular attitude.

We thus see the influence of the sensations upon the attitudes and motions, and these again react, by influencing the sensations. The different attitudes are favourable, or unfavourable, to the development of the external sensations. There are particular motions, peculiar to each sensation, which favour its action; besides, nearly all the senses have particular muscles, which favour their action, and which constitute an essential part of the apparatus, as we observe in the eye and ear.

Relations of the Attitudes and Motions to the Will.

The attitudes and motions which we have described, have the epithet *voluntary*, applied to them; because they are said to be under the immediate influence of the will. This assertion is true to a certain extent, but in some respects it is not; we shall therefore, further investigate this point.

In consequence of the determination of the will, a motion is produced, and there can be no doubt that the will causes the development of it. But all the phenomena which take place in the production of this motion, are not under the control of the will. I can move my hand or arm, but I am unable to contract singly, or together, the muscles of this part, if I have not an idea of the motion to be produced. This is equally true of all those muscles which we consider entirely submissive to the will. If we should undertake to contract the *obturator externus*, or any other muscle which does not produce of itself any determinate motion, we should find that this would be impracticable.

We may then assert, that the cause determining the motion is the will, but that the production of the muscular contraction necessary to execute this motion, is not dependent upon that cerebral action called the will, but is purely instinctive.

From these considerations it may be inferred, that the *will*, and the *action of the brain*, which produce directly the contraction of the muscles, are two distinct phenomena. But the direct experiments of modern physiologists, particularly of Legallois, have clearly established the truth of this. These experiments have demonstrated, that the will has its seat in the cerebum and cerebellum, but the direct cause of these motions seems to reside in the spinal marrow. If we separate the spinal marrow from the rest of the brain by an incision near the occiput, we prevent the will from determining and directing these motions, though they are nevertheless executed. As soon, however, as the separation takes place, they become irregular in extent, rapidity, duration, and direction.

If the action of the brain which produces muscular contraction be a phenomenon distinct from the will, we may easily conceive why, in certain cases, the motions are not produced, although the will commands them; and why, under different circumstances, very extensive and powerful motions take place without any participation of the will, as we frequently see in diseases. For the same reason we may conceive, why it is very difficult, and often impossible, for us to assume a new attitude, or to execute a motion for the first time; why the arts of dancing, fencing, &c. which depend upon the rapidity and precision of our motions, are only acquired by long exercise. Why, in a word, it frequently happens, that we exercise certain motions more perfectly, when our mind is not fully directed to it, than when our whole attention is concentrated upon it.*

* This doctrine has been confirmed by the experiments of Dr. Wilson Philip.—*Philos. Trans.* 1815.

Relations of the Attitudes and Motions to Instinct and the Passions.

We have seen that a great number of what are called the *voluntary motions and attitudes*, are under the dominion of *instinct*. There are a great number of attitudes and motions, both partial and general, which essentially depend upon it.

All the instinctive sentiments which essentially depend upon organization, such as sadness, fear, joy, hunger, thirst, when carried to a certain degree, induce attitudes and motions which are peculiar to them, and indicate their existence. It is the same in the natural passions, and all the instinctive phenomena, which the social state developes.

Most of the passions impel us to move, and increase very much the intensity of muscular contraction, as we observe in excessive joy, and anger, and, in some instances, in fear. Others of the passions stupify us, and render all kinds of motion impracticable, such as great chagrin, and certain sorts of terror; often extreme joy produces the same effect. This is the reason why the pantomimic art is exercised with so much success, in exhibiting the violent passions.

Relations of the Motions to the Voice.

These are intimate, inasmuch as both phenomena are the immediate effects of muscular contraction; with this difference, that in the voice we hear the effect, and see it in the motions.

There are certain motions which essentially depend upon organization; they in this respect resemble a *cry*. There are modes of voice which are acquired in social life; a great number of motions are acquired in the same manner. The voice and motions unite in the production of speech; these two are our principal and almost only means of expression. They aid each other, and sometimes supply each other's place. A man who finds difficulty in expressing himself, uses much gesticulation, but the reverse is generally the case with those whose elocution is easy. In the expression of the more powerful passions, they are united. It is rare that in expressing strong feelings, we do not unite gesture with speech.

It has been remarked, that the modifications which the motions and voice undergo by age, are very analogous; we shall find the same result, if we study the manner in which they are modified by age, sex, temperament and habit.

We shall finish, with these considerations, the description of the functions of relation. These functions possess the common character of being suspended, or remaining, during certain intervals, in a state of repose, or *sleep*. It would seem, therefore, proper, that the history of sleep should immediately follow the description of the functions of relation. But, as the nutritive and generative functions are both influenced by sleep, we prefer entering upon the examination of them first, which will be done in the next volume.*

* This is the end of the first volume, which was published in 1816; the second did not appear until a year afterwards. As this division of the work, has no reference to the arrangement of its matter, I have thought it sufficient simply to announce the fact.—*Trans.*

OF THE

FUNCTIONS OF NUTRITION.

The common end to which the nutritive functions tend, is the *nourishment* of the body, by which is meant that peculiar internal motion, by which all the parts of animal bodies are decomposed and recomposed simultaneously.

These functions are six in number, viz. 1st. Digestion, 2d Absorption, and the course of the chyle. 3d. The course of the lymph. 4th. The course of the venous blood. 5th. Respiration. 6th. The course of the arterial blood.

After having given a description of these functions, the relation which they have to each other, and to those of the functions of relation; we shall examine the different secretions, not as functions, but as the actions of insulated organs, and finish by giving a history of the function of nutrition itself.

OF DIGESTION.

The immediate object of digestion is the formation of the chyle, a substance which is destined to repair the loss which the animal economy is constantly suffering. The digestive organs contribute also in several other ways to nutrition.

Of Aliments and Drinks.

We give the general appellation *aliment*, to every substance which is capable of nourishing the body, when it is submitted to the action of the digestive organs. According to this definition, all aliments are necessarily composed either of animal or vegetable substances; for it is only those bodies which have enjoyed life, which are capable, for any length of time, of serving the purposes of nutrition in animals. But this definition of aliment is perhaps too restricted; for it may be fairly doubted, whether, in the strictest sense, the name of aliment should not be applied to those substances, which, though they may not be said to nourish the body, yet concur powerfully in nutrition, inasmuch as they enter into the composition of the animal organs and fluids. Such, for example, as muriat of soda, oxide of iron, silex, and especially of water, which is found in so large a quantity in the bodies of animals, and is so necessary to them. It will, therefore, be more proper to consider every substance an aliment which may assist in nutrition; preserving, however, the important distinction between those substances which are capable of performing this alone, and those which act in concert with them.*

Of Aliments.—Aliments differ from each other, with respect to the immediate principles which predominate in their composition. They may be divided into nine classes, viz. 1st. *Farinaceous* aliments, wheat, barley, oats, rice, rye, indian corn, potatoes, sago, salop, peas, beans, and lentils. 2d. *Mucilaginous* aliments—carrots, turnips, asparagus, cabbage, lettuce, mushrooms, melons, &c. 3d. *Sweet* aliments—different kinds of sugar, figs, dried dates and raisins, apricots, &c. 4th. *Acid* aliments—oranges, gooseberries, cherries, peaches, raspberries, mulberries, pears, apples, sorrel, &c. 5th. *Oily* and *fatty* aliments—cocoa, olives, sweet almonds, filberts, walnuts, animal fat, oils and butter, &c. 6th. *Caseous* aliments—different kinds of milk, cheese, &c. 7th. *Gelatinous* aliments—the tendons, aponeuroses, chorion, cellular tissue, and young animals, &c. 8th. *Albuminous* aliments—the brain, nerves, eggs, &c. 9th. *Fibrous* aliments—the flesh and blood of different animals.

* It was said by Hippocrates, that there are many kind of aliments, but that there is at the same time but one aliment. This proposition I have never been able clearly to understand. Did he mean that in every alimentary substance there is but one part which is nutritious? If so, this part will vary in each aliment. O did he mean that all substances when converted into chyle are essentially the same? This is not the case, for the qualities of the chyle vary according to the nature of the food. Did he mean that the aliment served to renew in the blood a particular substance, which alone nourishes the body, and which is the "*quod nutrit*" of the ancients? But does any such substance exist? Can we believe that there is in all aliments, a particular principle, every where the same and essentially nutritive? Nothing is farther from being proved.

We may add to this list a great number of substances which are employed as medicines; but which no doubt have a nutritive effect, or at least some of their immediate principles, such are manna, tamarinds, vegetable extracts, sugars, animal and vegetable decoctions, commonly called *ptisans*, &c.

Among the aliments, few are used in the state in which they naturally exist. They generally require to be prepared before being submitted to the action of the digestive organs. The mode of preparation varies infinitely, according to the kind of aliments, people, climates, customs, and degree of civilization; indeed, fashion is not without its influence upon the art of preparing food.

In the hands of a skilful cook, alimentary substances change almost entirely their nature, form, consistence, odour, taste, colour, and chemical composition, &c. So entirely is the change effected, that it is often impossible to recognize the substance which constitutes the principal ingredient in some dishes. The proper object of the art of cookery, is to render the aliments agreeable to the senses, and easy of digestion; but it rarely stops here. Frequently, among people in an advanced stage of civilization, the object, as well as the ambition of the artist, is to excite an impaired and fastidious appetite, or to satisfy an eccentric and capricious taste; so far from being a useful, it then becomes a most pernicious art, and leads to an infinite variety of distressing diseases, or even to premature death.

Of Drinks.—By the term drink, we understand some fluid, which, when it is introduced into the digestive organs, slakes the thirst, and repairs the loss which we habitually sustain, of the fluid part of our humours. We must, therefore, consider drinks as true aliments.

Drinks are divided according to their chemical composition; 1st. *water of different kinds*, as spring, well, and river water; 2nd. *syrups, vegetable and animal infusions*, as lemon and gooseberry syrups, whey, tea, coffee, &c. 3d. *Fermented liquors*, wine of various kinds, beer, cider and perry; 4th. *alcoholic liquors*, brandy, alcohol, ether, rum, &c.*

* Vide Encyclopedié methodique and the Dictionaire des Sciences medicales, article aliment.

Apparatus of Digestion.

If we judge of the importance of a function, from the number and variety of the organs which concur to effect it, digestion will occupy the first rank. No other function in the animal economy presents an apparatus so complicated.

There exists an evident relation between the food of the animal and the digestive apparatus. If the aliments differ essentially in their nature from the elements which compose the animal; if, for example, the food is *herbaceous*, the apparatus will be of large dimensions and complicated. If, on the other hand, the animal is nourished by flesh, its digestive organs will be less numerous and more simple, as we see in carnivorous animals. The food of man, being both animal and vegetable, he preserves a medium between the complicated digestive apparatus of herbivorous, and the simple apparatus of carnivorous animals, and is, therefore, called *omnivorous*. It seems hardly necessary to remark, that there are a great number of substances which are used as aliments by animals, which are of no utility to man, in this respect.

We may describe the digestive apparatus as a long canal, convoluted upon itself, large in some places and small in others, susceptible of being enlarged and diminished, and into which are poured a great quantity of fluids, by means of certain ducts. Anatomists divide the digestive organs into several portions; 1st. the mouth; 2nd. the pharynx; 3d. the œsophagus; 4th. the stomach; 5th. the small intestines; 6th. the large intestines; 7th. the anus.

Structure of the Digestive Canal.

The walls of this canal, are formed by two membranous laminæ, through its whole extent. The internal lamina, which is destined to be in contact with the aliments, consists of a mucous membrane, the aspect and structure of which vary in different portions of the canal; it is different in the pharynx from the mouth, in the stomach from the œsophagus, &c. At the lips and anus this membrane is lost in the skin.

The second lamina, which constitutes the wall of the canal, is composed of two strata of fibres; the one of which is longitudinal, and the other circular. The arrangement, thickness, and nature of the fibres, which enter into the composition of these strata, are different, according as they are observed in the mouth, œsophagus, or large intestines, &c.

A great number of blood-vessels are sent to, and arise from this canal, but the abdominal portion receives incomparably the largest part. The superior part only receives a sufficiency to answer the purposes of nutrition, and the inconsiderable secretion of which it is the seat; but the number and volume of the vessels which appertain to the abdominal portion, indicate that it is intended as the agent of a considerable secretion. The chyliferous vessels take their rise, exclusively, from that portion of the canal called the small intestines.

The nerves are distributed over the canal in a reversed order from the blood-vessels. That is, the cephalic, cervical and pectoral parts receive more than the abdominal portion, with the exception of the stomach, where the nerves of the eighth pair terminate. The remainder of the canal does not receive, scarcely, a branch of the cerebral nerves. The only nerves which can be distinguished, proceed from the sub-diaphragmatic ganglions of the great sympathetic. We shall see, by and by, the relation which exists between the mode of distribution of the nerves, and the functions of the superior and inferior portions of the digestive canal.

The bodies which pour out fluids into the digestive canal are, 1st. the *digestive mucous membrane* itself; 2nd. the *insulated follicles*, which are scattered in great number through the whole extent of this membrane; 3d. *agglomerated follicles*, which are met with at the entrance of the œsophagus, between the pillars of the veil of the palate, and, sometimes, at the junction of the œsophagus and stomach; 4th. the *mucous glands*, which exist in considerable numbers in the walls of the cheeks, the arch of the palate, near the œsophagus; 5th. the *parotid, submaxillary, and sublingual glands*, which secrete the saliva that is poured into the mouth; the *liver* and *pancreas*, the first of which pours out the bile, and the second the pancreatic juice, by distinct ducts, into the superior part of the small intestines, which is called the *duodenum.*

All the digestive organs contained in the abdominal cavity, are immediately covered, in a manner more or less complete, by a serous membrane, called the *peritoneum*. This membrane, from the manner in which it is arranged, and its physical and vital properties, serves important purposes in the act of digestion, either by preserving in the organs their respective relations, or by favouring their variations of volume, and preventing any friction upon each other, or the neighbouring parts.

We shall give the necessary details concerning the apparatus of digestion, after we have explained their functions. We shall confine ourselves, at present, to some remarks on the organs of digestion, considered during life, but at the time when they are not executing their peculiar functions.

Remarks on the Digestive Organs of Man and living Animals.

The surface of the mucous membrane of the digestive canal, is always lubricated by a stringy, viscous substance which is poured out, more or less abundantly. It is observed in the largest quantity in those parts where no follicles exist; a circumstance which seems to shew, that these are not the only secretory organs. One part of the substance, generally called mucus, continually evaporates, so that there constantly exists a certain quantity of vapour, in each part of the digestive canal. The chemical nature of this substance is not well known. It is transparent, with a slight greyish tint, it adheres to the membrane which forms it; its taste is salt, and the application of certain tests shews that it is acid. Its formation continues for some time after death takes place. That which is formed in the mouth, pharynx, and œsophagus, is propelled into the stomach, and mixed with the secretions of the mucous glands and saliva, by the action of deglutition, which frequently takes place. It would seem from this, that the stomach, when there are no aliments in it, contains a considerable quantity of this mixture of mucus, follicular secretion, and saliva. This is a point, however, which is not confirmed by the experience of most persons. Nevertheless, it is evident that this exists in some persons, their stomach being known in the morning to contain several ounces of this mixture. In some cases, it is frothy, very viscid, and slightly clouded, holding suspended *floculi* of mucus. Its taste is plainly acid, but not disagreeable; it is sensibly perceived by the throat, and acts upon the teeth, so as to diminish the polish upon their surface, and to prevent their gliding easily upon each other. This fluid, when applied to the tincture and paper of litmus, causes them to turn red.*

Under different circumstances, in the same individual, with the same appearances as relates to colour, transparency, and consistence, this fluid, when taken from the stomach, has neither the taste nor other properties of acids; sometimes it is slightly salt. Neither a solution of potash, nor sulphuric or nitric acids, produce any apparent effect upon it.

One of my former pupils, Dr. Pinel, who possessed the faculty of vomiting at will, informed me, that he frequently evacuated from the stomach, in the morning, three ounces of this fluid. Some of this liquid was examined by M. Thenard, who found it composed of a large quantity of water, some mucus, and some salts, the base of which were soda and lime; there was no acidity perceptible either by the tongue or reagents. The same physician, recently, sent me about two ounces of a fluid obtained in this way. M. Chevreul analysed it and found a large proportion of water, a considerable quantity of mucus, the lactic acid of Berzelius, a small quantity of animal matter, soluble in water, but insoluble in alcohol, some hydro-chlorate of ammonia, hydro-chlorate of potash, and hydro-chlorate of soda.

With respect to the quantity of this fluid, M. Pinel observes, that if he had swallowed a mouthful of any aliment, he could obtain it in any quantity, in a short time, even to half a pound. M. Pinel thinks that the taste of this fluid varies, according to the sort of aliment he had used the night before.

When we examine the bodies of persons who die suddenly, and whose stomachs had not recently received either food or drink, this organ is only found to contain a very small quantity of acid mucus adhering to its walls, and of which, that part which is found in the pyloric portion of the viscus, appears reduced into chyme. It is, then, extremely probable that the fluid which passes into the stomach is digested, as an alimentary substance, which is the reason of its not accumulating.

* Vide Experiments on Digestion in Man, by S. de Montegre, 1804.

In animals, the organization of which resembles man, as dogs and cats, we do not find any fluid in the stomach, after some days of absolute abstinence; we only find a little viscid mucus adhering to its walls, at the splenic extremity. This substance has a very great analogy, in its physical and chemical properties, with what we find in the stomach of man. But if we cause animals to swallow a body, which is not susceptible of being digested, a pebble for example, there is formed, after some time, in the cavity of the stomach, a mucous, acid fluid, of a greyish colour and sensibly salt taste, which resembles, in its composition, the mucus we often meet with in man, the analysis of which, by M. Chevreul, has already been given.

This fluid which is composed of the mucous secretions of the mouth, pharynx, œsophagus and stomach, with the fluid secreted by the follicles of these parts, and the saliva, has received from physiologists the name of gastric juice, to which they have attributed peculiar properties.

In the small intestines, there is formed a large quantity of mucous substance, which remains constantly attached to their internal walls. This differs little, in its sensible qualities, from that which we have spoken of above; it is viscid, ropy, and somewhat salt and acid in its taste; it is very rapidly renewed. If we lay bare the mucous membrane of this intestine in a dog, and remove from it the mucus which will be found there, absorbing it with a sponge, a minute will scarcely pass before it is replaced. We may repeat this experiment as frequently as we choose, until the intestine becomes inflamed, in consequence of the contact of air and other foreign bodies. When the mucus penetrates into the cavity of the small intestines, it is in the form of a pulpy, greyish, opaque matter, which has the peculiar appearance of a particular chyme.

The bile and the fluid secreted by the pancreas, are poured out into that portion of the canal which is called the *duodenum.* I believe that no one has ever observed in man, during life, the manner in which the bile and pancreatic juice are poured out. In animals, dogs for example, this fluid oozes out at intervals, that is, about twice in a minute, we see spring from the orifice of the biliary duct, a drop of bile, which spreads itself uniformly over the surrounding parts, which are already impregnated by it.

Thus there is always found in the small intestines a certain quantity of bile. The oozing of the fluid formed by the pancreas, takes place in a similar manner, but much more slowly. A quarter of an hour often elapses, before we see a drop of this fluid pass out from the orifice of the duct, which pours it into the intestines. I have, however, in some instances, observed it to ooze out with much more rapidity.

The different fluids which are deposited in the small intestines, viz. the chyme which comes from the stomach, the mucus, the follicular fluid, the bile and pancreatic juice, are mixed together, but, in consequence of its properties, and perhaps of its proportion, the bile predominates, and gives to the mixture its colour and taste. A great part of this mixture descends towards the large intestines. In its passage, its consistence is increased, and it becomes of a bright yellow colour, though at first of a deep yellow, and afterwards green. There is, however, a great difference in this respect, in different individuals.

In the large intestines, the mucous and follicular secretion, appears to be less active, than in the small intestines. This admixture of fluids, after it has arrived at the large intestines, acquires a much greater degree of consistency, and a fetid odour, analogous to that of other fecal matter.

The knowledge of these facts enables us to conceive how a person, who has made no use of aliments, continues to evacuate the canal; and how, in some diseases, the quantity discharged is very great, although the patient may have been for a long time deprived of every alimentary substance, even liquid. Near the anus, there are found follicles which secrete an oily fluid, which has a strong and peculiar odour. We find, almost constantly, gas in the intestinal canal; the stomach contains very little. The chemical nature of this gas has not yet been examined with care, but, as the saliva which we swallow is always impregnated with atmospheric air, it is probable that it is this gaseous fluid more or less modified; I have ascertained by experiment, that it is partly composed of carbonic acid. The small intestines contain a very small quantity of gas; it is a mixture of carbonic acid, azote and hydrogen. The large intestines contain carbonic acid, azote and hydrogen, and sometimes carbonated, and at others sulphuretted, hydrogen. I saw twenty-three *centiemes* of this gas in the rectum of a criminal lately executed, though the large intestines did not contain any fecal matter.

We may ask, what is the origin of these gases? Are they derived from the external air, or secreted by the mucous membrane of the canal, or are they results of the chemical action of the substances contained in the canal? We shall examine these questions hereafter; in the meantime we will remark, that we are in the habit of swallowing much more atmospheric air than we are aware of.

The muscular coat of the digestive canal, in relation to the different modes of contraction which it excites, must be noticed. The lips, the jaws, generally the tongue, and the cheeks, move by a contraction, perfectly analogous to that of locomotion. The veil of the palate, the pharynx, œsophagus, and, in some particular circumstances, the tongue, exhibit motions which have a manifest analogy to muscular motion, but differ from it, in being executed without the participation of the will. I have, however, seen some persons who could move the veil of the palate, and the superior parts of the pharynx at will.

I would not, however, be understood to say, that the motions of the parts, of which I have been speaking, take place without nervous influence, for experience proves the reverse of this. If, for example, we divide the nerves which pass to the œsophagus, we deprive this part of its contractile power.

The muscles of the veil of the palate, those of the pharynx, and two thirds of the superior part of the œsophagus, do not act as digestive organs, except when they thrust forward substances from the mouth towards the stomach. The inferior third of the œsophagus presents a peculiar phenomenon, which it is important to understand. This is an alternate contraction and relaxation, which continually take place. This begins at the point where the two superior thirds of the canal unite with the inferior third. It is prolonged, with a certain degree of rapidity, to where the œsophagus is inserted into the stomach. Once produced, it continues for an indefinite time, its medium duration is about thirty seconds. While the inferior third of the œsophagus is thus contracted, it is as hard and elastic as a tense cord. The relaxation which succeeds this contraction, occurs suddenly and simultaneously, through the whole extent of the contracted fibre, but, in some cases, it seems to take place from the superior towards the inferior part. In a state of relaxation, the œsophagus presents a remarkably flaccid appearance, which is strongly contrasted with its state of contraction.

This motion of the œsophagus depends upon the nerves of the eighth pair. When we divide these nerves, the œsophagus no longer contracts, but it does not remain in the remarkable state of relaxation which we have described. Its fibres, independently of this nervous influence, continue to contract themselves with a certain force, and the canal remains in an intermediate state between contraction and relaxation. The emptiness or distension of the stomach has an influence upon the intensity of the contractions of the œsophagus.*

From the lower part of the stomach to the end of the rectum, the intestinal canal exhibits a mode of contraction which differs, in almost every respect, from that of the part of the canal which is above the diaphragm. This contraction is always made slowly and irregularly, an interval of an hour often takes place without our being able to perceive any trace of it; at other times, many portions of it contract at a time. It appears very little under the influence of the nervous system; it will continue, for example, in the stomach after we have divided the nerves of the eighth pair; it becomes more active by debilitating animals, and even by death; in some cases it becomes considerably accelerated by it; it remains even when the intestinal canal has been separated from the body. The pyloric portion of the stomach, and the small intestines, are the parts of the canal, where this contraction takes place most frequently and regularly. This motion, which results from the successive, or simultaneous contraction of the longitudinal and circular fibres of the intestinal canal, has been designated by different names by authors. It

* The alternate motion of the inferior third of the œsophagus does not take place in the horse; but in this animal, the pillars of the diaphragm have a particular action on the cardiac extremity of this duct, which does not take place in those animals which vomit easily. See the detail of experiments made by me on this subject, and the Report of the Committee of the Institute in the "Bulletin de la Societée Philomatique, Anneé. 1815."

has been called *vermicular*, *peristaltic*, and *organic sensible contractility*. Whatever it may be, the will does not exert any sensible influence upon it. The muscles of the anus contract voluntarily.

The super-diaphragmatic portion of the canal is not capable of undergoing any considerable dilatation. It is easy to see, by its structure and the mode of contraction of its muscular coat, that it will not permit aliments to remain in its cavity, but that it is rather destined to transport these substances from the mouth to the stomach. The stomach and large intestines, on the other hand, evidently admit of great distension; the substances introduced into the canal, also accumulate and remain longer in them, than in the other parts.

The diaphragm and abdominal muscles keep up a continual action upon the digestive organs, contained in the abdomen. They exert upon these organs a continual pressure, which becomes sometimes very considerable. We shall see, below, how these two causes, singly or together, concur in the different acts of digestion.

Of Hunger and Thirst.

Before digestion in man and animals can take place, it is necessary, that a certain number of actions should precede, by which the food is seized, triturated and introduced into the stomach. This introduction necessarily ceases when the stomach is full, and ought only to take place to such an extent, as will satisfy the demands of the economy; and in general it is best, that it should not be done until the preceding digestion is terminated; there are also other circumstances where it is injurious. It was, therefore, necessary, that man and animals should be informed of the moment when it was proper to receive solids or liquids into their stomach, and of the circumstances in which it was improper. Nature has effected this important purpose, by imparting to us many instinctive feelings, which inform us of the wants of the economy, and of the particular state of the digestive organs. These feelings vary according to their kind. They may be divided into those which excite us to use some particular substances, and into those which induce us to desire something remote and difficult to be obtained. The first relate to *hunger* and *thirst*, and the second to *satiety* and *disgust.*

Of Hunger.

The desire of solid aliments is characterized by a particular sensation in the region of the stomach, and some degree of debility. In general, this sensation is produced when the stomach has remained empty for some time. The intensity differs very much in different individuals, and even in the same individual at different times. With some, its violence is extreme, with others, it is scarcely perceptible; some never experience it, and only eat because the hour of repast has arrived; many persons feel an oppression more or less painful, in the epigastric region; in others, there is a gentle heat in the same region, accompanied with yawning, and a particular noise, owing to the displacement of the gas contained in the intestines, this noise is technically called *borborygma.* When this desire is not satisfied, it increases very much, and at last it becomes very painful, and a sensation of general weakness and fatigue is induced, which may go to the extent of rendering locomotion difficult, and even impossible.

Authors distinguish hunger into local and general phenomena. This distinction, is in itself proper and may perhaps be advantageous to the student; but have not mere gratuitous suppositions, the existence of which are barely possible, been described as the local or general phenomena of hunger? This is one of those points in physiology in which the deficiency of direct experiment is most palpably felt.

The contraction of the stomach has been reckoned among the number of the local phenomena of hunger. "The walls of the viscus, it is said, become thicker; it changes its form and situation, and is drawn a little towards the duodenum. This cavity contains the saliva mixed with air, mucus and hepatic bile which has flowed back by the action of the duodenum. These different humours are accumulated in the stomach, in proportion to the duration of the fasting. The cystic bile does not run into the duodenum, but remains in the gall bladder; and is more abundant and black, in proportion to the duration of the abstinence. There is a change in the order of the circulation of the digestive organs; the stomach receives less blood, either in consequence of the flexuous course of its vessels, then greater because its coats are drawn together, or in consequence of the compression of its nerves from this contraction, the influence of which upon the circulation will be diminished. On the other hand, the liver, spleen, and epiploon, in receiving more blood, perform the office of a *diverticulum;* the liver and spleen, because they are less supported when the stomach is empty, and therefore, offer a more free access to the blood; and the epiploon, because then its vessels are less flexuous, &c."* The most of these propositions are merely conjectures, and are nearly destitute of proof. They have been already in part refuted by Bichat, though some of the objections of this ingenious physiologist are themselves exposed to criticism. Not being able to enter into the details of this discussion, I shall only relate the experiments I have made myself on this subject.

After twenty-four, forty-eight, and even sixty hours of complete abstinence, I have never seen this contraction of the stomach, of which authors speak. This organ has always presented dimensions sufficiently large, especially at its splenic extremity. Until the expiration of the fourth or fifth day, I have not found the stomach to change its capacity or to alter, even slightly, its position; even then, the effects are not very remarkable, except the fasting has been rigorously observed.

Bichat thinks that the pressure sustained by the stomach, when it is empty, is equal to what it supports when it is distended by aliments, as the abdominal walls contract, in proportion as the volume of the stomach diminishes. There is no difficulty in satisfying ourselves of the incorrectness of this opinion. If we introduce our two fingers into the cavity of the abdomen, after its walls have been divided, we shall find, by direct experiment, that the pressure upon the viscera of this cavity, is in proportion to the distension of the stomach. If the stomach be full, the fingers will be pressed strongly, and the viscera will be forced through the opening; if it be empty, the pressure will be slight, and the effort of the viscera to escape, trifling. We must not confound in this experiment, the pressure exerted by the abdominal muscles, when they are relaxed, with that which is produced when

* Vide Dictionaire des Sciences, Medicales, article digestion.

they contract forcibly. Also, when the stomach is empty, all the reservoirs contained in the abdomen, are more readily allowed to become distended with their natural contents. This, I believe, is the principal cause of the accumulation of the bile in the *vesicula fellis*. With respect to the presence of the bile in the stomach, which some persons suppose produces the sensation of hunger, I believe that, in certain morbid conditions, the bile is not introduced into this organ, though it may continue to be constantly thrown out into the small intestines.

The quantity of mucus existing in the cavity of the stomach becomes less as the abstinence is prolonged. My experiments on this point entirely agree with those of Dumas. With respect to the quantity of blood sent to the stomach, when it is empty, from the size of its vessels, and the mode of circulation which takes place there, I am induced to believe, that it receives less of this fluid than when it is distended with food. But instead of differing, in this respect, from the other abdominal organs, it appears to me to be common to them all.

We include, under the general phenomena of hunger, a weakening and diminution of action in all the organs; the circulation and respiration become slower, the heat of the body less, the secretions diminish, and all the functions are performed with difficulty. It has been said, however, that absorption becomes more active; but there is no conclusive evidence of this.

Appetite, which is the first degree of hunger, must be distinguished from the inclination we have to prefer one sort of food to another. These sensations differ essentially from hunger, which is an expression of the true wants of the economy; they are peculiar, in a great degree, to civilization, habits, and certain ideas relative to the properties of aliments. Some arise from season and climate, and then they become as natural as hunger itself; such is the inclination we have for a vegetable diet in warm climates, or in the heat of summer.

There are some circumstances which render hunger more intense, and cause it to return after shorter intervals; such as the cold and dry air of winter, cold baths, dry friction of the skin, exercise on horseback, walking, fatigue of body, and, in general, all those causes which accelerate the action of the organs of nutrition, with which hunger is essentially connected. Some substances when introduced into the stomach excite a sensation analogous to that of hunger, but which, however, should not be confounded with it.

There are circumstances which diminish the intensity of hunger, and which retard the periods when it habitually manifests itself, such as the moisture or warmth of the climate, repose of the body and mind, the gloomy passions, in a word, all those causes which diminish the action of all the organs, and particularly those of nutrition. We also know that certain substances, when introduced into the stomach, prevent the action of the organs, and cause the sense of hunger to cease, as opium and warm drinks, &c.

The proximate causes of hunger have been, in turn, attributed to a great variety of circumstances; as the foresight of the vital principle, the friction of the walls of the stomach on each other, the mechanical action of the liver upon the diaphragm, the action of the bile upon the stomach, the acridity and acidity of the gastric juice, the fatigue of the contracted fibres of the stomach, the compression of the nerves of this viscus, &c. &c. Hunger is produced, like all other internal sensations, by the action of the nervous system, and it has no other seat than in this system itself, and no other causes than the general laws of organization. What proves the truth of this assertion is, that it continues often when the stomach is distended with aliment, and again, it does not occur, although the organ has been empty for a long time. In a word, it is governed by habit, so as to cease spontaneously when the hour of repast has passed. This is true, not only as relates to the sensation experienced in the region of the stomach, but also the general weakness which accompanies it, and which, of consequence, cannot be considered real, at least in the first instant, when it is manifested.

Many authors confound hunger with the effects of a complete abstinence, prolonged until death is produced. We shall not follow their example, in this respect. Hunger, considered as an instinctive phenomenon, belongs to physiology, but considered as a cause of disease, it pertains to pathology.

Of Thirst.

We give the name thirst to that sensation which induces us to desire drink. It differs in different individuals, and is not the same always even in the same person, at different times. In general, it consists in a sense of dryness, constriction, and heat in the back part of the mouth, pharynx, œsophagus, and often the stomach itself. After thirst has continued, even for a short time, these parts become red and swollen, and the secretion of the mucus ceases almost entirely; that of the follicles becomes altered, thick, and tenacious; the flow of saliva diminishes, and its viscidity sensibly increases. These phenomena are accompanied with an indefinite sense of uneasiness, and general heat, the eyes become red, the spirits agitated, the motion of the blood accelerated, the respiration short and laborious, the mouth widely opened, in order to bring the external air in contact with the irritated parts, to obtain a momentary relief.

The desire of drink is increased by certain causes, such as the heat and dryness of the atmosphere, which cause a great loss of the fluid parts of the body; it is also manifest under a great number of circumstances, such as having spoken long, eaten certain aliments, or having swallowed any substance which remains in the œsophagus, &c. The pernicious habit of drinking frequently, and the desire to taste certain drinks, wine, brandy, &c. excites a sensation which strongly resembles thirst.

There are some persons who never perceive the sensation of thirst, who seem to drink merely to imitate others, but who are capable of living for a long time without thinking of it, or feeling any inconvenience from being deprived of it. There are others, in whom thirst often takes place, and becomes very imperious, so as to induce them to drink from twenty to thirty pounds of fluid in the twenty-four hours. We observe a great difference in this respect in individuals.

We shall not pretend to go back, with some writers, to the proximate cause of thirst, or suppose that it is the effect of the foresight of the soul, nor shall we presume to appoint to it a place, either in the nerves of the pharynx, or in the sanguineous, or lymphatic vessels; because we hope that such considerations will not hereafter, find a place in scientific treatises on physiology. Thirst is an internal sensation, an instinctive sentiment, it is a result of organization, and does not admit of any explanation. We shall not say more of the morbid phenomena which accompany, and precede death, arising from a deprivation of drink, this entirely belongs to morbid physiology.

Of the particular Acts of Digestion.

Those acts which together constitute digestion, are, 1st. prehension; 2nd. mastication; 3rd. secretion of saliva; 4th. deglutition; 5th. action of the stomach; 6th. action of the small intestines; 7th. action of the large intestines; 8th. expulsion of fecal matter.

All these actions do not equally concur in the production of the chyle; the action of the stomach and of the small intestines are alone absolutely indispensable.

The digestion of solid aliments requires these eight digestive actions; that of drink is much more simple, it only requires prehension, deglutition, and the action of the stomach and small intestines. It is very rare that drinks pass to the large intestines. We shall first consider the digestion of aliments, and afterwards that of drinks.

Of the Prehension of solid Aliments.

The organs of prehension are the superior extremities, and the mouth. We have already spoken of the superior extremities, and we now propose to say a few words of the different parts which constitute the mouth.

Anatomically speaking, the mouth is that oval cavity formed above, by the palate and superior maxillary bone; below, by the tongue and inferior maxilla; laterally, by the cheeks; posteriorly, by the veil of the palate and pharynx, and anteriorly by the lips. The dimensions of the mouth vary in different individuals, and are capable of being enlarged in every direction; from above below, by the depression of the tongue, and separation of the jaws; transversely, by the separation of the cheeks; and from the anterior to the posterior part, by the motion of the lips and veil of the palate.

The jaws more particularly influence the form and dimensions of the mouth; the superior constitutes an essential part of the face and only moves with the head; the inferior, on the contrary, is possessed of great mobility. The jaws are garnished with small hard bodies, called *teeth;* they are generally considered as bones, but they differ from bone in some important respects; particularly in their structure, mode of formation, uses, and from their not being altered by the contact of the air; but they resemble them in their hardness and chemical composition. There are three kinds of teeth; the incisors, which occupy the anterior part of the jaws; the molares, which occupy the posterior part; and the canine, which are situated between the incisors and molares.

We divide the teeth into two parts, the crown and the root, which differ in their structure. As the crowns of the different kinds of teeth are required to perform different sorts of service, their form varies. That of the molares, or grinders, is cubical, the canine are conical, and the incisors flat, with a cutting edge. Whatever is its form, the crown is excessively hard, but it is worn away like dead matter by constant friction.

The fang, or roots, fulfil in the three kinds of teeth one common use, that of effecting a solid junction with the jaw, and of transmitting to them the powerful impressions made upon the teeth. They are received into cavities, which are called *alveolar processes*, and exactly fill them. It would appear that the walls of these cavities exert a considerable pressure upon the roots of the tooth from the fact that they contract, and at last are filled up when the roots of the teeth are removed.

The incisors and canine teeth have but one root, the molares have generally several, but whatever may be their number, they have always the form of a cone, the base of which corresponds to the crown, and the apex to that part, which ends in the alveolar process. In some cases, they present curvatures, more or less remarkable.

The edge of the alveolar process is covered with a thick, fibrous, resisting coat, which is called the *gum;* this coat is nicely fitted round the inferior part of the crown of the teeth, adheres strongly to them, and thus gives solidity to the junction of the teeth with the jaws. This coat is capable of bearing strong pressure, without inconvenience; we readily see the advantages which result from this arrangement.

We must include in the number of organs that assist in the prehension of aliments, the muscles which move the jaws, particularly the lower jaw; and the tongue, the motions of which have a considerable influence on the dimensions of the mouth.

Mechanism of the Prehension of the Aliments.

Nothing is more simple than the prehension of the aliments; it consists in the introduction of alimentary substances into the mouth. For this purpose the hands seize the food and divide it into small portions, capable of being contained in the mouth, and then introduce it into this cavity; perhaps, by the assistance of instruments convenient for this purpose.

But in order that it may penetrate into this cavity, it is necessary that the jaws should separate, in other words that the mouth should open. It was long discussed whether, in opening the mouth, the inferior jaw only moved; or whether both jaws separated from each other at the same time. Without entering into this discussion, which does not merit the importance that has been attached to it, we will observe, that it is obvious that the inferior jaw moves alone when the mouth is open moderately; but when it is opened very widely, the superior jaw is raised, that is, the head is thrown slightly back on the vertebral column. But, in every case, the inferior jaw has much the greatest extent of action, unless its depression is prevented by some physical obstacle; then the opening of the mouth depends alone upon the retraction of the head upon the vertebral column; or what is the same thing, upon the elevation of the upper jaw.

In most cases, when the aliment is introduced into the mouth the jaws are brought together for the purpose of retaining it, and causing it to undergo the process of mastication and deglutition. But sometimes the elevation of the lower jaw assists in the prehension of the aliments. We have one example of this in our manner of biting fruit; the incisors bury themselves, in opposite directions, in the alimentary substance, and act like the blades of scissors, detaching a portion of the mass. This motion is principally produced by the contraction of the elevator muscles of the inferior jaw, which represents a lever of the third kind; the power being at the insertion of the elevator muscles, the fulcrum in the temporo-maxillary articulation, and the resistance in the substance on which the teeth act.*

* In carnivorous animals, where this mode of prehension is frequently employed, the three kinds of teeth participate, especially the canine.

The volume of the substance, placed between the incisor teeth, influences the force with which they are pressed together. If the volume be small, the force will be much greater, for all the elevator muscles are inserted perpendicularly into the jaw, and the sum of their forces is employed to move the lever which it represents. If the volume of the body be such that it can scarcely be introduced into the mouth, even if the resistance be but little, the incisor teeth will be incapable of dividing it; because the masseter, crotophite, and internal pterygoid muscles, being inserted very obliquely on the jaw, thus lose a great part of the power with which they contract.

When the effort of the muscles of the jaws is not sufficient to detach a portion of the alimentary mass, the hands assist in the separation. On the contrary, the muscles on the posterior parts of the neck draw the head strongly backwards, and, from the combination of these two efforts, a portion of the aliment is detached and remains in the mouth. In this mode of prehension, the incisor and canine teeth are employed, but it is rare that the molares assist.

By the succession of the motions of prehension, the mouth is filled, and from the elasticity of the cheeks, and the depression of the tongue, a large quantity of aliment may be accumulated. When the mouth is full, the veil of the palate is depressed, and its inferior edge applied to the base of the tongue, so that all communication between the mouth and pharynx is interrupted.

Mastication and Mixture of the Saliva with the Aliments.

Independently of what we have said of the mouth, as relates to the prehension of aliments, it is necessary to understand the uses it fulfils in masticating and mixing the food with the saliva; it is proper to remark, that fluids, arising from different sources, abound in the mouth. The mucous membrane which lines the mouth; the numerous single, or agglomerated follicles we observe on the internal surface of the cheeks at the junction of the lips with the gums; the back part of the tongue; and the anterior surface of the veil of the palate, and uvula, pour out continually the fluid which they form on the internal surface of the mouth. It is the same of the mucous glands, which exist, in great numbers, in the substance of the palate and cheeks. Lastly there are six glands, three on each side, which are called the parotids, submaxillary, and sublingual, that pour out the saliva they secrete into the mouth. The first are placed between the ear and the jaw, and have each an excretory duct, which opens on a level with the second upper molar teeth. The ducts of the maxillary glands terminate on each side of the frenum of the tongue, near which those of the sublingual glands also open.

It is probable that these fluids vary in their physical and chemical properties, according to the organ which forms them, but chemistry has not yet determined these differences by direct experiments. The mixture, which we know by the common name of *saliva*, has been carefully analysed.

Among the alimentary substances deposited in the mouth, some traverse this cavity without undergoing any change; others, on the contrary, remain for a considerable time, and experience several important modifications. The first are soft and nearly fluid aliments, the temperature of which differs little from that of the body. The second, are those which are dry, hard, or fibrous, and those, the temperature of which differs, more or less, from that peculiar to the animal economy. They have both, however, this quality in common, that, in passing through the mouth, they are appreciated by the organs of taste.

There are three principal modifications, which the aliments undergo in the mouth, 1st. change of temperature; 2d. admixture with the fluids which are poured into the mouth, and sometimes solution in these fluids; 3d. pressure, more or less strong, and comminution, which destroys the cohesion of the parts. They are, besides, easily and frequently transported from one point of this cavity to the other. These three modes of alteration do not take place successively, but simultaneously, each favouring the other.

The change of temperature in the aliments retained in the mouth, is evident; the sensations which they excite, are sufficient evidence of this. If they have a very low temperature, they produce a vivid sensation of cold; which continues until they have absorbed a sufficient quantity of caloric to approach the temperature of the walls of the mouth. The reverse takes place when the temperature is more elevated than that of its walls.

Our judgment, in this instance, is formed in a manner similar to that by which we judge of the temperature of those bodies which touch the skin. We institute a comparison between the temperature of the atmosphere, and that of the body which is in contact with the mouth; so that a body preserving the same temperature, will appear at one time cold, and at another warm, according to the temperature of the bodies which had been before in contact with the mouth.

The change of temperature which the food undergoes in the mouth, is a mere accessory phenomenon. Its trituration, and intimate admixture with the fluids poured into this cavity, are the circumstances which merit a particular attention. As soon as the aliment is introduced into the mouth, it is pressed by the tongue against the palate and the cheeks. If the aliment has little cohesion, this simple pressure of the tongue is sufficient to spread it over the mouth; but, if it be partly fluid and partly solid, it presses out the fluid part which is swallowed, and the solid alone remains in the mouth. The tongue produces this effect readily, as the tissue is muscular, and as it is supplied with a great number of muscles which are destined to move it.

It seems surprising, that a body as soft as the tongue, should exert an action sufficiently strong to crush a body, which presents even a slight resistance. But this is owing to the circumstance, that it hardens at the same time that it contracts itself; besides, the mucous membrane which lines its superior surface, is composed of a thick, dense, and fibrous coat. Such are the phenomena which are observed, when the aliments offer but little resistance; but if they cohere more strongly, they are then submitted to the action of the *masticating organs.*

The essential agents of mastication are, the muscles which move the jaws, the tongue, the cheeks and the lips; the maxillary bones and teeth can only be considered as instruments.

Though the action of both jaws may assist in mastication, it is almost entirely performed by the lower jaw. This bone is capable of being elevated and pressed strongly against the upper jaw, and moved forward, backwards, and sideways. These different motions are produced by numerous muscles which are attached to the bone; but the jaws could not fulfil the function to which they are destined, if they were not garnished with teeth, the physical qualities of which render them particularly adapted to this purpose.

A few remarks on these bodies are necessary to clearly understand what follows.—The use of the molar teeth is to grind the food; they are twenty in number, ten in each jaw, five on the right and five on the left side. The form of their crown is that of an irregular cube; the corresponding surfaces are composed of pyramidal eminences, varying in number in the different teeth. In the anterior molares they are small, but large in the posterior. These asperities and cavities, are so arranged that those of the upper correspond with those of the lower jaw.

At the lower and middle part of the crown, there exists a cavity, filled with an organ, which, in the early periods of life, secretes the tooth. The root is hollowed out into a canal, which is occupied by an artery, vein, and filament of a nerve. The substance which forms the teeth, is of an excessive hardness, particularly its external coat, or *enamel.* Being destined to crush bodies, the resistance of which is sometimes very great, it is necessary that they should present a proportional degree of hardness; more especially as they are destined to exercise this office during life, and it is, therefore, necessary that they should be worn away very slowly. On this account, extreme density was indispensable, for any body, however hard it may be, cannot fail to be worn down by continued friction.

The substance which forms the body and root of the teeth, is homogeneous in all its parts; the enamel, on the contrary, which composes the crown of the tooth, presents fibres which are arranged perpendicularly to the surface of the bony part of the tooth, and strongly adhering to it. The phosphate and carbonate of lime constitute nearly the whole of the teeth in man. In 100 parts, 99.5 are of this salt, the remainder being animal matter.* In the enamel, there is scarcely any animal matter, and it is to this circumstance that we must attribute its whiteness and excessive hardness

We have already shewn how solid the articulation of the teeth with the jaw is; the molar teeth, in consequence of the office

* I have found, from experiment, that the proportion of animal matter is very great in herbivorous animals, and still greater in carnivorous. The proportion of carbonate of lime is greater in herbivorous animals, than it is in those which are carnivorous, or in man.

which they perform, possess this firmness in the highest degree; their roots are also more numerous, though not so large as in those which have but one. Finally, whether single or double, their form is conical, and they are received into cavities to which they are adapted, which are called alveolar processes; each tooth represents a wedge buried in the jaws. The teeth in each jaw, together, form what are called the dental arches.

The form of the arch is the half of a parabola, the inferior being somewhat larger than the superior The inferior edge of the upper is a little inclined outwards, but that of the lower inwards. These edges present, at that part formed by the molar teeth, a groove, bounded by two ranges of eminences. When the jaws are brought together, the incisors and canine teeth of the lower jaw are placed behind the superior. The external, projecting edge of the inferior dental arch enters the groove of the superior arch. When the edges of the incisors are brought in contact, there is an interval left between the molar teeth. To add firmness to the junction of the teeth with the jaws, nature has so arranged them that the sides of nearly all are in contact, which in this way present a particular *facette*. The result of this disposition is, that when one of the teeth is exposed to a considerable pressure, it is supported by all the teeth which compose the arch.

These facts being known, it is easy to understand the explanation of the mechanism of mastication.

Mechanism of Mastication.

When mastication begins, the lower jaw is depressed, an effect which is produced by the relaxation of the elevator and the contraction of the depressor muscles. The food is introduced within the dental arches, by the tongue, or some other means. The inferior jaw is then raised by the masseter, internal pterygoid, and temporal muscles, the contraction of which is proportioned to the resistance of the aliments. The food being pressed between two unequal surfaces, the asperities of which grind against each other, is divided into small portions; the number of which is proportioned, to the facility with which they are acted upon.

But a single motion of this kind only affects one part of the aliments contained in the mouth, and it is required that all should undergo this operation. This is effected by a succession of motions of the inferior jaw, by the contraction of the muscles of the cheek, tongue, and lips, which carry, successively and promptly, the aliment between the teeth, when the jaws are separated, so that it may be crushed when they are brought together. When the food is soft, two or three movements of the jaws are sufficient to divide all that is contained in the mouth; each of the three different kinds of teeth performing their part. But the mastication must be prolonged when the substances are tough, fibrous or coriaceous, we then use only the molar teeth, and generally those of one side at a time, as if to enable the other to remain at rest. In using the molar teeth, the resisting arm of the lever, which is represented by the lower jaw, is shortened and thus rendered more favourable to the power which moves it.

The teeth are submitted to a very considerable power during mastication, which would inevitably loosen, if not displace them, if they were not very strongly articulated with the jaws. Each root acts like a wedge, and transmits to the alveolar processes, the force with which it is pressed.

The advantage arising from the conical form of the root, is by no means doubtful. In consequence of this form, the force which presses upon the tooth, and tends to thrust it into the jaw, is divided; one part has a tendency to separate the walls of the alveolar process, the other to thrust it inwards, thus the force, instead of being transmitted to the extremity of the root, which must have taken place, if it had been cylindrical, is applied to the whole alveolar surface. The molar teeth, which have to endure considerable force, have several roots; or at least one very large root. The incisor and canine teeth, which have but one root, and that not very large, are never compelled to endure a very strong pressure.

If the gums had not presented a smooth surface, and a dense tissue, placed as they are about the necks of the teeth and filling up their intervals, they would have been subject every instant to be torn; for in the mastication of hard substances of an irregular form, they are every moment exposed to be pressed strongly by the edges and angles of these substances. This inconvenience is actually felt, whenever their tissue is softened, as in scorbutic affections.

During mastication, the mouth is closed posteriorly by the veil of the palate, the anterior face of which is applied against the base of the tongue; anteriorly, the food is retained by the teeth and lips.

Admixture of the Aliments.

When we have an appetite, the sight of aliments determines a considerable afflux of saliva to the mouth. In some persons this is sufficiently strong for the saliva to be projected to the distance of several feet. I have actually seen an instance of this. The presence of aliment in the mouth, excites this secretion. While the aliments are bruised and triturated by the organs of mastication, they imbibe these fluids, which are copiously poured into the mouth at this time, especially the saliva. It is easy to conceive, that the division of the aliment, and the frequent displacement which it undergoes during mastication, will singularly favour its admixture with the mucus and salivary fluids. In their turn, these fluids facilitate mastication, by softening the aliment. The greater number of alimentary substances, when submitted to the action of the mouth, become dissolved or suspended, wholly, or in part, in the saliva, and at this moment become proper to be introduced into the stomach, and are soon swallowed. In consequence of its viscidity, the saliva absorbs the air which is combined with it in the various movements which are required in mastication, but the quantity of air absorbed in this way is inconsiderable, and has been generally much exaggerated.

We cannot say, positively, what purpose is answered by the trituration of the food, and its admixture with the saliva; whether it be a simple division, which renders it more convenient for the alteration which it is destined to undergo in the stomach, or whether it experiences in the mouth the first degree of animalization. We will however remark, that the taste and odour of the aliment are altered during mastication, and that when mastication is prolonged, it in general, renders digestion more prompt and easy. On the contrary, that persons who do not chew their aliments, have frequently, from this circumstance alone, slow and imperfect digestion. We know when mastication and the admixture of the saliva are carried to a sufficient extent, by the degree of resistance of the aliments, and the taste which they excite. Besides, the walls of the mouth, and especially the tongue, being endowed with the sense of touch, can appreciate the physical changes which take place in the aliments. Some authors have attributed this to the uvula of the palate.* I much doubt, however, the correctness of this opinion. The uvula, from its situation, has no connexion with the aliment during its mastication. I have often noticed persons who had lost the uvula, either by a venereal ulcer, or by excision, and I have never found that their mastication or deglutition were the least deranged.

Of the Deglutition of Aliments.

We understand by deglutition, the passage of a solid, liquid, or gaseous substance, from the mouth into the stomach. The deglutition of solid aliments, will first occupy our attention.

Though apparently simple, deglutition is by far the most complicated of all the muscular actions, which assist in digestion. It is produced by the contraction of a great number of muscles, and requires the concurrence of many important organs. All the muscles of the tongue, those of the veil of the palate, the pharynx, larynx, and the muscular coat of the œsophagus, assist in deglutition. We ought to have an exact and detailed knowledge, if we wish to form a just idea of this act. The nature of this work will not admit of our explaining all the anatomical details. We shall limit ourselves to a few remarks, upon the veil of the palate, the pharynx, and œsophagus.

The *veil of the palate* is a sort of valve, attached to the posterior edge of the arch of the palate; its form is four sided. The inferior, or loose edge, is prolonged into a point, which is called the *uvula*. Like other valves of the intestinal canal, the veil of the palate is essentially formed by a duplicature of the digestive mucous membrane; there enters into its composition many

* It is, say they, a vigilant sentinel, which judges when the aliment can be swallowed without inconvenience. It keeps a watch upon the organs of deglutition, and upon the stomach, which, according to the impression it has received, is disposed to receive or reject it.

mucous follicles, especially about the uvula. It is moved by eight muscles, viz. the two *internal pterygoid*, which elevate it; the two *external pterygoid*, which stretch it transversly; the two *pharyngo-staphylini* and the two *glosso-staphylini* which draw it down. These four last extend to the lower part of the throat, and are there covered by the mucous membrane, and form the *pillars of the veil of the palate*, between which are situated the *tonsils;* a collection of mucous follicles. The opening comprehended between the base of the tongue below, the veil of the palate above and the lateral pillars, is sometimes called the *isthmus of the throat.*

By means of this muscular apparatus, the veil of the palate undergoes many changes of position. Its most common situation is vertical; one of its faces being anterior and the other posterior. In certain circumstances, it becomes horizontal, it then has a superior and an inferior face, and its loose edge corresponds to the concavity of the pharynx. This last position is determined by the contraction of the elevator muscles.

Bichat asserts, that the elevation of the veil of the palate may be carried to such an extent, as to be applied to the opening of the posterior nares; this motion seems to be impracticable; there is no muscle arranged in such a manner as to produce it, and the disposition of the pillars evidently oppose it. The depression of the veil is executed by the contraction of the muscles which form the pillars. We have already remarked, that these motions are not submissive to the will in a great number of individuals.

The *pharynx*, is a sort of vestibule, into which the nasal fossæ, the eustachian tubes, the mouth, the larynx, and œsophagus open. It fulfils important functions in the production of the voice, in respiration, in hearing and digestion. The pharynx extends from the *basilary process* of the occipital bone, to which it is attached above, to a level with the middle part of the neck below. Its transverse dimensions are limited by the os-hyoides, the larynx, and the aponeurosis of the *pterygo-maxillaris*, to which it is attached. The mucous membrane, which covers it interiorly, is distinguished by the development of its veins, which form here a very remarkable net-work. Near this membrane is the muscular coat, the circular fibres of which, form the three constrictor muscles of the pharynx, and the longitudinal fibres of which are represented by the *stylo-pharyngeus* and the *pharyngo-staphylini* muscles. The contractions which these muscles execute, are not in general submissive to the will.

The *œsophagus* is immediately attached to the pharynx, and is prolonged to the stomach, where it terminates. Its form is cylindrical, it is united to the surrounding parts, by a loose and extensible cellular tissue, which adapts itself to its dilatation and other motions. To penetrate into the abdomen, the œsophagus passes between the pillars of the diaphragm, with which it is intimately united.

The mucous membrane of the œsophagus is white, thin, and delicate; it forms longitudinal folds, which facilitate its dilatation. Above, it is lost in the pharynx. Dr. Rullier has lately called the attention of anatomists to several indentations formed in its lower part, which terminates by a sort of fringed edge, hanging loose into the cavity of the stomach.*

We meet in its substance, a great number of mucous follicles, and we distinguish on its surface the orifices of many excretory ducts of mucous glands. The muscular coat of the œsophagus is thick, and its tissue more dense than the pharynx, its longitudinal fibres are more external and less numerous, the circular are placed on the interior, and are very numerous.

Near the pectoral and inferior part of the œsophagus, the eighth pair of nerves form a plexus, which embraces the canal and sends many filaments to it. The contraction of the œsophagus is made without any participation of the will.

Mechanism of Deglutition.

For the better understanding of the subject, we shall divide deglutition into three stages. In the first the aliments pass from the mouth into the pharynx; in the second they pass over the openings of the glottis, and nasal fossæ, and arrive at the œsophagus; in the third they pass through this canal, into the stomach.†

* There is between the mucous membrane of the œsophagus and the stomach in man as striking a difference, as that which exists between this same membrane in the cardiac and pyloric half, in the stomach of a horse.

† For the division of deglutition, see my Thesis, defended in the School of Medicine at Paris, 1808.

Let us suppose a common case, that, for example, we have swallowed several times a part of the aliment in the mouth, as its mastication has been completed.

As soon as there is a certain quantity of food masticated, it is placed on the superior surface of the tongue, by the action of mastication, without any necessity, as some have supposed, that the apex of this organ should pass into all the angles of the mouth, to collect it together. Mastication then ceases; the tongue is elevated, and applied to the arch of the palate, successively, from the apex to its base. The portion of aliment placed on its superior surface, having no other way to escape from the pressure to which it is exposed, is directed towards the pharynx; where it meets with the veil of the palate applied over the base of the tongue, which it causes to be elevated, the veil becoming horizontal. The tongue continuing to press the aliments, they would be carried towards the nasal fossæ; if this was not prevented by the tension which the veil receives from the external *peristaphilini* muscles, and especially by the contraction of its pillars. It becomes thus capable of resisting the action of the tongue, and of contributing to direct the aliments towards the pharynx.

The muscles which more particularly act in applying the tongue to the arch of the palate and to the veil of the palate, are the proper muscles of this organ, aided by the *mylo-hyoideus*. This terminates the first stage of deglutition. The motions are all voluntary, with the exception of those of the veil of the palate. The phenomena take place in succession, and with little promptitude, they are few in number and easy to comprehend.

The same remarks will not apply to the *second stage*. There, the phenomena are simultaneous, multiplied and produced with such rapidity, that Boerhaave considered them a sort of convulsion. The space which the morsel has to pass over in the second stage is very short, being only from the middle to the lower part of the pharynx. But it must be prevented from entering either the glottis or the nasal fossæ, where it would prove injurious. Besides, its passage must be so rapid as not to interrupt, but for a moment, the free communication between the external air and the larynx. We shall now see how nature accomplishes this important purpose.

The morsel of food no sooner reaches the pharynx than every part of it is thrown into action. It at first contracts itself, embracing and holding firm the morsel of food; the veil of the palate, drawn down by its pillars, acts at the same time. On the other side, and almost at the same instant, the base of the tongue, the os-hyoides, and the larynx are elevated, and carried forward, so as to meet the morsel and facilitate its passage over the opening of the glottis. At the same time that the os-hyoides and larynx elevate themselves, they approach each other; that is, the superior edge of the thyroid cartilage is pressed behind the body of the os-hyoides, the gland of the epiglottis is pushed backwards, the epiglottis itself depressed, and inclines downwards and backwards, so as to protect the entrance of the larynx. The cricoid cartilage executes a rotation upon the inferior horns of the thyroid, from which it results, that the entrance of the larynx becomes oblique from above downwards, and from before, backwards. The morsel glides over its surface, and continuing to be pressed by the contraction of the pharynx, and the veil of the palate, it arrives at the œsophagus.

It will not require much consideration to understand the position which the epiglottis in this case assumes, if it be considered as the only obstacle which prevents the entrance of the aliments into the larynx, at the moment of deglutition. But I have shown, by a series of experiments, that this cause can only be considered as accessory. We can in fact, entirely remove the epiglottis from an animal, without deglutition being impeded. Let us inquire then, what is the reason why no part of the food is introduced into the larynx, at the moment of swallowing. At the instant that the larynx is elevated, and forced behind the os-hyoides, the glottis is closed with great exactness. This motion is effected by the same muscles which contract the glottis in the production of the voice. So that, if we divide the laryngeal and recurrent nerves of an animal, leaving the epiglottis untouched, we render deglutition extremely difficult, because we have taken away the principal cause which prevents the introduction of the aliment into the glottis. Immediately after the morsel has passed the glottis, the larynx descends, the epiglottis is raised, and the glottis again opened to give passage to the air.*

From this explanation, it is easy to comprehend how the aliments, when swallowed, arrive at the œsophagus, without penetrating into any of those openings which are so numerous in the pharynx. The veil of the palate, at the moment when the pharynx contracts itself, protects the posterior nares, and the orifices of the eustachian tubes; the epiglottis, and especially the motion by which the glottis is closed, protects the larynx.

We have thus finished the description of the second stage of deglutition, and traced the morsel of food, as it has passed through the mouth and pharynx, until it has arrived at the upper part of the œsophagus. All the phenomena exhibited in the second stage, take place simultaneously, and with great rapidity; they are not controlled by the will, and differ, therefore, in many respects, from the phenomena observed in the first stage.

The third stage of deglutition has been examined with less care; in consequence, probably, of the situation of the œsophagus, which it is not easy to observe, except at its cervical portion. The phenomena are not complicated. By its contractions, the pharynx pushes the morsel into the œsophagus, with sufficient force to dilate the superior part of this organ. Its superior circular fibres, excited by the presence of the morsel, contract and thrust the aliment towards the stomach, causing the distention of those parts which are below; these again contract in their turn, and this action is repeated; until the morsel arrives at the stomach. In the two superior thirds of the œsophagus, the relaxation of the circular fibres immediately follows the contraction, by which the morsel is displaced. It is not the same in the inferior third, which remains contracted for some time after the introduction of the food into the stomach.

We should be mistaken, if we supposed, that the passage of the morsel through the œsophagus was very rapid. I have been

* I have known two instances of individuals, in whom the epiglottis was entirely wanting, but in whom deglutition was performed without any difficulty: If in a laryngeal phthisis, with destruction of the epiglottis, deglutition is imperfect and labourious, it arises from the arytœnoid cartilages being carious, and the edges of the glottis ulcerated; so that they become incapable of closing exactly the opening of the glottis.

See my Memoir upon the Epiglottis, read before the Institute of Paris, 1813.

astonished, in my experiments, to find how slow its progress is; often two or three minutes elapse before it reaches the stomach; at other times, it stops and remains for a considerable time on each spot. I have seen it, in some instances, rise from the inferior extremity of the œsophagus towards the upper part, and afterwards descend. When any obstacle prevents its entrance into the stomach, this motion is repeated a great number of times, before the aliment is rejected by the mouth. This explains the sensation we often perceive, of the aliment remaining in the œsophagus, which induces us to drink, in order to make it descend into the stomach.

When the morsel is very large, its progress is still more slow and difficult. It is accompanied by a vivid sense of pain, produced by the distention of the nervous filaments, which surround the pectoral portion of the canal. Sometimes the morsel is arrested entirely, and occasions the most serious accidents.

Professor Halle observed, in a woman affected by a disease which enabled him to see the interior of the stomach, that the arrival of a portion of aliment in this viscus, was immediately followed by the formation of a sort of *hood*, at the cardiac orifice. This *hood* was formed by the displacement of the mucous membrane of the œsophagus, which was thrust into the stomach by the contraction of the circular fibres of the canal.

The whole extent that the morsel has to pass over, during the three stages of deglutition, is copiously lubricated by mucus. The morsel pressing out the contents of the follicles, which it meets in its passage, glides easily along the mucous membrane. We may remark, that at those points where the morsel passes most rapidly, and is pressed with the most force, the mucous secretory organs are the most numerous. For example, in the narrow space where the second stage of deglutition takes place, there are found, the tonsils, the fungous papillæ at the base of the tongue, the follicles of the veil of the palate, and of the uvula, those of the epiglottis, and the arytœnoid glands; in this respect, the saliva and mucus fulfil uses analogous to those of the synovia. The mechanism by which we swallow the other morsels, does not differ from what has been above related.

Nothing can be easier than to execute deglutition, while nearly all the acts which compose it, are beyond the influence of the will and under the dominion of instinct. We are incapable of altering a single motion of nutrition. If the substance contained in the mouth is not sufficiently masticated, if it does not possess the form, consistence, and dimensions of the alimentary morsel; and if the motions of mastication, which immediately precede deglutition, have not been made, with all our exertions, we shall be unable to swallow it. How common a thing is it to see persons incapable of swallowing a pill, and who are obliged to have recourse to various means to introduce it into the stomach.

In order to form an idea of the part which the will takes in deglutition, we may make the following experiment upon ourselves. Let any one endeavour to execute five or six motions of deglutition, in which he swallows the saliva. The first, and even the second time, this will be easy accomplished; but the third time it will be more difficult, because there will remain but little saliva in the mouth; the fourth it will be impossible to execute until a certain period will elapse, when new saliva will be thrown into the mouth; but the fifth and sixth will be impracticable, because there will not be any saliva to swallow. Every one may recollect how difficult deglutition is, whenever the mouth and pharynx are dry.

Of the Abdomen.

The digestive actions, which remain to be examined by us, take place in the cavity of the abdomen, the disposition of which deserves to be studied with attention.

The abdomen is the largest of the cavities of the body, and admits of the greatest augmentation of its capacity. It contains a great number of organs, which are destined to perform certain important functions, as generation, digestion, secretion of urine, &c. Its walls are chiefly muscular, and have a very marked action on the organs they contain. The form of the abdominal cavity is irregularly ovoid. In consequence of its large dimensions, and in order to give precision to language, it is divided into several regions, which have each received a particular name.

To understand this division, which is purely artificial, it will be necessary to suppose two horizontal planes, one of which divides the abdomen on a level with the crests of the ilii, and the other on a level with the inferior false ribs. The part of the abdomen placed beneath the first plane, is called the *hypogastric* region, that which is found above the second, the *epigastric*, and that comprehended between the two planes, the *umbilical.*

Suppose, now, that two vertical planes, passing from the side of the head, should fall upon the anterior and inferior spines of the ilium, dividing the abdomen from before, backwards, it is plain, that each of the three abdominal regions, of which we have been speaking, will be subdivided into three compartments, of dimensions nearly equal. It will be found convenient to designate these subdivisions by the following names. The middle may be called the *epigastrium*, and the two sides the *hypochondriac regions;* the umbilical region, called right, left, and middle; lastly, we may give the name of *hypogastrium*, to the middle division of the hypogastric region, while we call the sides the iliac regions.

By means of these artificial divisions, we may fix, with exactness, the position and respective relations of the organs contained in the abdomen; which will be found extremely convenient, both in physiology and medicine.

Above, the abdomen is separated from the chest, by the diaphragm, a muscle disposed in the form of an arch, and the contraction of which has a great influence on the position, and even upon the action of the organs contained in the abdomen. The circumference of the diaphragm is attached to the edge of the false ribs, and the vertebral column. In a state of relaxation, its centre is raised to a level with the sixth and seventh true rib, but at the instant that this muscle contracts strongly, it occasions a considerable diminution of the abdominal cavity, compresses all the organs which it contains, and distends the soft parts which form its walls.

The inferior part of the abdomen is formed by the pelvis, the firm bones of which support the weight of a part of the viscera, and allow a place of insertion for the muscles, but do not assist in producing variations in the capacity of the abdomen, except under circumstances extremely rare. It is proper to remark, that the space comprehended between the *coccyx*, the *tuberosities of the ischiia*, and the arch of the pubis, is filled with soft parts, and particularly by the *ischio-coccygeus*, and the *elevator* and *external sphinctor ani muscles.*

Anteriorly, and laterally, the walls of the abdomen are formed by the abdominal muscles. These muscles, as we have already seen, concur powerfully in the different attitudes and motions of the trunk, and have, also, effect in digestion and generation, &c. Among these muscles, those which are large, and situated on the sides, are destined to contract the abdomen, and to compress the viscera which are contained in it.

The long muscles, situated anteriorly, are most generally the antagonists of the first. They resist their action and may, under certain circumstances, augment the dimensions of the abdomen, and diminish the pressure which the viscera support.

From the ensiform cartilage, to the pubis, there exists a fibrous line, formed by the crossing of the fibres of the aponeuroses of the abdominal muscles; this is called by anatomists the *linea alba.* Its uses will hereafter be explained.

Most generally, the muscles which compose the abdominal walls, are directed by the will, but there are also circumstances where they instinctively contract, when they display a much greater degree of energy than in ordinary cases.

Action of the Stomach upon the Aliments.

Thus far we have only seen the physical actions of the digestive organs upon the aliments, we shall now examine those actions which are almost entirely chemical. In the stomach, the aliments are transformed into a substance peculiar to animals, which is called *chyme.* But before treating of the phenomena which its formation presents, we will say a few words of the stomach itself.

Of the Stomach.

The stomach is placed between the œsophagus and the duodenum; it occupies, in the abdomen, the epigastric, and a part of the left hypochondriac region; its form, though variable, is, in general, that of a *conoid*, curved upon itself. The left half of the stomach is always much larger than the right, and, as these two halves take a different part in the formation of the chyme, I have thought it useful to name the one the *splenic half*, because it is in contact with the spleen; and the other the *pyloric half*, because it corresponds to the pylorus. These two parts are frequently separated from each other by a particular contraction.

The stomach being destined to allow the aliments to accumulate in its cavity, it is evident that its dimensions, situation in the abdomen, and relations with the neighbouring organs, must undergo great variations. This organ has two orifices; the one corresponds to the œsophagus, which is called the cardiac orifice; the other communicates with the small intestines, and is called the intestinal, or pyloric orifice.

The three membranes, or tunics, which compose the stomach, present dispositions the most favourable to variations in the volume of the organ. The exterior, or peritoneal coat, is formed of two laminæ, slightly adhering to the viscus. These are prolonged, without uniting, for a considerable distance from its edge, and thus form what is called the *epiploon*, or *omentum*, the extent of which is, therefore, in an inverse ratio to the volume of the stomach.

The mucous membrane of the stomach is of a reddish white and marbled; it presents a great number of irregular folds, situated particularly on the inferior and superior edges of the organ; they are also seen on its splenic extremity. They are the more numerous and remarkable when the stomach is contracted upon itself.

There is no part of the digestive mucous membrane, which presents so many, and such fine villosities as the stomach. It is constantly covered on its splenic half, by a mucus adhering to its surface. We also meet with many follicles in its substance, but it is important to observe, that they are very abundant in the pyloric portion. We see a certain number in the neighbourhood of the cardiac orifice, they are rare in the other parts of the membrane.

At the pylorus, the mucous membrane forms a circular fold, called the *valve of the pylorus*. Between its two laminæ is found a dense, fibrous tissue, designated by some authors, by the name of the *pyloric muscle.*

With respect to the muscular coat of the stomach, it is very thin; its circular and longitudinal fibres are separated from each other, especially on the splenic part; this separation increases or diminishes with the volume of the stomach.

There are few organs which receive so much blood as the stomach; four arteries, of which three are large, are sent exclusively to it. Its nerves are not less numerous, they are composed of the eighth pair, and of a great number of filaments coming from the *solar plexus* of the *great sympathetic.*

Accumulation of Aliments in the Stomach.

Before explaining the changes which the aliments undergo in the stomach, it is necessary to be acquainted with the phenomena of their accumulation in this viscus, and the local and general effects which result from them.

The first morsels which are swallowed, are easily lodged in the stomach. This organ is but little compressed by the surrounding viscera; its walls easily separate, and yield to the force with which the morsels are thrust into the organ. But, as new portions of aliment arrive, its distention becomes more difficult, for it must be accompanied with a pressure of the other viscera, and an extension of the abdominal walls. It is, especially towards the cardiac extremity, and the middle part, that the accumulation takes place, the pyloric portion is not so readily distended.

At the same time that the stomach is distended, its form, relations, and even its position become modified. Instead of being flattened, and occupying only the epigastrium, and left hypochondriac region, it assumes a rounded form; its large *cul de sac* is buried in this hypochondrium, and fills it up, almost entirely. The large curvature descends towards the umbilicus, or navel, especially on the left side. The pylorus, however, fixed by a fold of the peritoneum, preserves its positions and relations with the surrounding parts.

In consequence of the resistance offered by the vertebral column posteriorly, the stomach is not dilated in this direction. The result, therefore, is, that the viscus is entirely carried forward; and, as the pylorus and œsophagus cannot be displaced in this direction, it undergoes a rotary motion, by which its large curvature is directed forward, its posterior face inclined below, and its superior upwards.

In undergoing these changes of relation and position, however, it preserves a conoid figure, curved upon itself, which is peculiar to it. This arises from the manner in which the three tunics contribute to its dilatation. The two laminæ of the serous membrane are separated, and give way to the stomach; the muscular undergoes a true distension; its fibres elongate, but so as to preserve the peculiar form of the stomach; lastly, the mucous membrane yields, especially in those parts where its folds are most numerous, which it will be remembered, are the cardiac extremity, and along the large curvature.

The dilatation of the stomach alone, produces important changes. The whole extent of the cavity is augmented, the belly becomes prominent, the abdominal viscera compressed with more force, and often a desire of voiding the fœces and urine is felt. The diaphragm is crowded into the chest, and is depressed with difficulty; the action of respiration becomes less easy, and those phenomena which depend upon it, as speaking and singing, become modified, &c. In some cases, the dilatation of the stomach may be carried to such an extent, that the abdominal walls become painfully distended, and the respiration really difficult.

For the production of such effects, it is evident, that the contraction of the œsophagus, which thrusts the aliment into the stomach, must be very energetic. We have already spoken of the considerable thickness of the muscular coat of this canal, and the great number of nerves distributed to it. There is nothing but this peculiar structure, which can explain the force with which the aliments distend the stomach. To satisfy ourselves of this, we have only to introduce a finger into the œsophagus of an animal at its cardiac orifice, and we shall be surprised at the force with which it contracts. But if the aliments exert so marked an influence on the walls of the stomach and abdomen, they must themselves undergo a proportionate reaction, and tend to escape from the two openings of the stomach. It is generally said that this effect does not take place, in consequence of the firmness with which the cardia and pylorus close themselves; but this phenomenon has never been directly investigated.

The following experiments on this point, were made by myself. The alternate motion of the œsophagus prevents the return of the aliments into its cavity. The more the stomach is distended, the more intense and prolonged is this contraction, and the shorter the duration of the relaxation. The contraction, for the most part, takes place at the moment of inspiration, when the stomach is very strongly compressed. The relaxation happens frequently at the moment of expiration.

We can form an idea of this mechanism, by laying bare the stomach of a dog, and endeavouring to press back the aliments into the œsophagus, with both hands. We shall find it almost impossible to do this, whatever be the force we employ, if we make the attempt at the time the œsophagus is contracted; but this will be easily done, if we compress the viscus at the moment of relaxation.

The resistance which the pylorus opposes to the aliments, is of a different kind. In living animals, whether the stomach be full or empty, this opening is closed by the constant contraction of this fibrous ring, and the fibres, of which it is composed. We see frequently in the stomach another obstruction, one or two inches distant, which appears destined to prevent the aliments from arriving at the pylorus.* We may distinguish also irregular and peristaltic contractions, which begin in the duodenum, and are prolonged in the pyloric portion of the stomach, the effect of which is to thrust the aliments towards the cardiac portion. Besides, when the pylorus is not naturally and firmly closed, the aliment has but little disposition to introduce itself into this opening, as its natural tendency must be to pass in the direction where the pressure is least; and this will of course be as great in the small intestines as in the stomach, inasmuch as the pressure is nearly equal over the whole cavity of the abdomen.

In the number of phenomena produced by the presence of aliments in the stomach, there are several, the existence of which,

* This structure is very remarkable in carnivorous animals, and herbivorous animals with one stomach.

though generally admitted, have never been sufficiently demonstrated. Such for example, as the diminution of volume in the spleen, and sanguineous vessels of the liver and omentum; the motion of the stomach called by authors the *peristole*, which presides over the reception of aliments, distributing them equally, and exerting upon them a gentle pressure; so that its dilatation, so far from being passive, would be essentially active. I have frequently laid open the abdomen of animals, when the stomach was filled with aliment; and have often examined the bodies of criminals shortly after death, but I have never seen any thing to justify these assertions.

The accumulation of aliments in the stomach, is accompanied with several sensations, which it is proper to notice. The first is the agreeable sensation which we receive in gratifying this natural want. The sensation of hunger is gradually appeased, the general weakness, which accompanies it, is replaced by a new sensation of activity and vigour. But if more food be introduced, a sense of fulness and satiety is induced, which shows that the stomach is full. If, notwithstanding this instinctive warning, we persist in eating more, disgust and nausea supervene, and are shortly followed by vomiting.

These different sensations do not entirely depend upon the volume of the food; other things being equal, nutritious aliment induces soonest a sense of satiety. A substance which is but little nutritious, calms but imperfectly the sense of hunger, even when it is taken in considerable quantity. The mucous membrane, therefore, is endued with a considerable degree of sensibility, inasmuch as it distinguishes the nature of the substances brought in contact with it. This quality manifests itself in a very remarkable manner, when any poisonous substance is brought in contact with it, when it produces intense pain; we know also that it is sensible to the temperature of aliments.

From the redness of the mucous membrane, the quantity of fluid which it secretes, and the size of the vessels which are ramified upon it, we cannot doubt that the presence of aliments in the stomach produces an excitement, useful in the process of chymification. This excitation of the stomach has a powerful influence upon the general state of the functions, as will be shown hereafter.

The aliments remain in the stomach a considerable length of time, generally for several hours, during which they are formed into chyme. We will now examine the phenomena which attend this transformation, which has been, heretofore, but imperfectly investigated.

Alteration of the Aliments in the Stomach.

The aliment remains in the stomach, generally, about one hour before it undergoes any perceptible change, but what arises from its mixture with the fluids which are continually poured into this organ. During this time, the stomach remains uniformly distended; at last the pyloric portion contracts itself, through its whole extent, especially towards the point nearest to the cardiac portion, during which the aliments are forced back. From this time, we find in the pyloric portion, nothing but chyme, mixed with a very small portion of aliment unchanged.

The highest authorities have agreed in considering chyme as a homogeneous, pultaceous, greyish substance, of a sweetish insipid taste, slightly acid, which preserves some of the properties of aliments. But this description is far from being perfect. Indeed, the circumstances under which the chyme assumes these characters, and the sort of aliments which had been used, are not mentioned, though it is evidently important that they should be known. I thought that some new experiments on this subject would be useful. I shall not record here all the details of those which I have made, but only the most important results. There are as many kinds of chyme, as there are sorts of aliments, if we may judge from their colour, consistence, aspect, &c. This any person may easily satisfy himself of, by causing dogs to eat different sorts of simple alimentary substances, and killing them during the process of digestion. I have also repeatedly confirmed this observation in man, upon criminals, and persons dying suddenly from accidents.

In general, animal substances are more easily and completely altered than vegetable. It happens frequently, that these last traverse the whole of the canal, without changing their characters. I have often seen in the rectum and small intestines, greens, spinnage, &c. which had been added to the soup, preserving all their properties, their colour only being altered by the bile. The chyme is particularly formed in the pyloric portion. It would appear that the aliments are introduced by degrees, and that during their stay, they undergo a transformation. I have, however, often seen chymous matter on the surface of the mass of aliments which fill the cardiac portion; but generally, the aliments in this part of the stomach, preserve their peculiar properties.

It is difficult to say, why the pyloric portion is better suited to the formation of the chyme, than the rest of the stomach. Perhaps the great number of follicles observed there, induce some modification in the quantity or nature of the fluid secreted. The transformation of alimentary substances into chyme, takes place, generally, from the surface towards the centre. There is formed on the surface of the portions of aliment swallowed, a soft coat, easily detached. They appear to be acted upon by an agent, which completely dissolves them. A morsel of the white of an egg, boiled hard, for example, is acted upon as if it had been dipped in vinegar, or a solution of potash. Whatever may be the substance employed, the chyme has always a sour taste, and smell, and turns the purple juice of vegetables red. A very small quantity of gas is found in the stomach, during the formation of chyme, often it does not exist at all; sometimes it is formed like a small bubble, at the superior part of the cardiac portion. I have been able, by great care, in one instance, in the body of a criminal, recently executed, to collect a sufficient quantity of this gas for analysis. M. Chevreul found it composed of

Oxygen,	11.00
Carbonic acid,	14.00
Pure hydrogen,	3.55
Azote,	71.45
Total,	100.00

It is rare that we meet with gas in the stomach of a dog.

I cannot believe, with professor Chaussier, that with each act of deglutition we swallow a bubble of air, which is thrust into the stomach with the alimentary morsel. If this were the case, we ought to find in this organ a considerable quantity of air after eating, which is not the fact.

A large quantity of chyme does not accumulate in the pyloric portion of the stomach; the most I have seen was hardly equivalent, in volume, to two or three ounces of water. It would appear that the contraction of the stomach has an influence upon the formation of the chyme, from the following observations made by myself. After having remained for some time immoveable, the extremity of the duodenum contracts itself, which is followed by a similar action in the pyloric portion of the stomach. This motion forces the chyme towards the cardiac portion, but afterwards the contraction is made in an opposite direction; that is, after being distended, and having permitted the chyme to return anew into its cavity, the pyloric portion contracts itself from the left towards the right side, directing the chyme towards the duodenum, which overcomes the action of the pylorus, and penetrates into the intestine. This phenomenon is repeated for a certain number of times, after which it is stopped, and the same process is renewed. When the stomach contains much aliment, this motion is limited to that part of the organ nearest to the pylorus; but, as it becomes emptied, the motion extends itself more and more; and at last becomes manifest in the cardiac portion, when the stomach is nearly empty. In general, it becomes more distinctly marked towards the end of chymification. Some persons have a distinct consciousness of it at the time.

The pylorus has been supposed, by some, to act a very important part in the passage of the chyme, from the stomach to the intestine. It judges, according to some, of the degree of chymification of the aliments, it opens, and allows those parts to pass which possess the requisite qualities, but closes itself against those which do not present them. We know, however, from daily experience, that undigested and indigestible substances, as the stones of fruit, and other substances incapable of being converted into chyme, at last pass easily through it. These opinions, which are, in some degree, consecrated by the meaning of the term pylorus (a door keeper) may serve to amuse us, but they are after all mere hypotheses.

All alimentary substances are not transformed into chyme with an equal degree of facility. In general, fatty substances, tendons, cartilages, concrete albumen, and mucilaginous and sweet vegetables, resist longer the action of the stomach than those which are caseous, fibrous, or glutinous. Some substances are very difficult to digest, such as bone, the epidermis of fruits, and entire kernels of grain. In determining the digestibility of aliments, it is necessary to take into consideration the size of the portions which are swallowed. I have often observed that the largest masses remained longest in the stomach. On the contrary, a substance that is not even digestible, if it be minutely divided, as the stones of raisins, do not remain long in the stomach, but pass at once with the chyme into the intestine. As regards facility and promptitude, in the formation of the chyme, there is a vast difference among individuals. It is evident then, from what has been said, that in order to form an estimate of the precise time required for the conversion of all the food contained in the stomach into chyme, it would be necessary to know its quantity, chemical nature, degree of mastication, and the constitution of the individual. It is rare, however, that the transformation of the whole of the aliment into chyme requires more than four or five hours.

We do not know the precise nature of the chemical changes which take place in the stomach, though there have been, at differerent periods, many attempts to explain them. The ancient philosophers supposed that the aliments putrefied in the stomach; Hippocrates attributed digestion to *coction;* Galen supposed that the stomach possessed certain faculties, which he called *attractive*, *retentive*, *concoctive*, and *expulsive;* and thought he thus gave an explanation of digestion. The doctrine of Galen was received by the schools until the middle of the seventeenth century, when it was attacked and overthrown by the chemical sect of philosophers; who established on its ruins, the doctrine of a *peculiar fermentation*, by means of which the aliments were *macerated*, *dissolved*, *precipitated*, &c. This system did not retain its ground long, but was replaced by another much less reasonable. The doctrine which succeeded, was that of *trituration*, or a grinding down of the aliments, by the contraction of the stomach; it was also supposed, that an infinite number of small worms attacked and divided the aliments. Boerhaave thought he had approached nearer the truth, when he combined together the various opinions on this subject, which had prevailed before his time. Haller abandoned the doctrines of his master, and considered digestion as a simple maceration. He knew that vegetable and animal substances which are plunged in water, are soon covered with a coat, soft and homogeneous; and he supposed that the aliments underwent a similar process, by being macerated in the saliva, and gastric juices.

If we examine these different systems, by those severe rules of logic, which should always govern us in physiological inquiries, we shall be compelled to acknowledge, that they were mere flights of the imagination, which only served to conceal the absolute ignorance of their inventors. Was it any advance in knowledge to say, that digestion was a concoction, a fermentation, or a maceration? Certainly not, as it is impossible that any one can attach any precise meaning to these expressions, when applied to digestion. But this was not the method pursued by Reaumur and Spallanzani. They made experiments upon animals, and demonstrated that all these systems were false. They shewed, that when aliments were inclosed in hollow metallic balls, and pierced with small holes, that they were digested in the same manner, as if they were floating loose in the cavity of the stomach. They proved, that the stomach contains a peculiar fluid, which they called *gastric juice*, and that this fluid was the principal agent in digestion. But they exaggerated its qualities very much, and deceived themselves, when they supposed, that they had explained digestion, by considering it a *mere solution;* for, from their not explaining what they meant by this solution, they, in fact, did nothing towards shewing what the precise alteration is which the food undergoes in the stomach.

Instead of stopping to expose and refute these different hypotheses, which would be a very easy task, and which may be found in almost every treatise on physiology, we shall make some observations on the formation of chyme. It is necessary, in investigating this subject, to attend to the following points; *first*, to the circumstances in which the aliments, contained in the stomach, are found to exist; and, *second*, to the chemical nature of these substances. The circumstances in which the aliments are placed, during the time they remain in the stomach, which require to be noticed, are few in number. *First*, they experience a pressure, more or less strong, of the abdominal walls, and of those of the stomach; *second*, they are affected by the the motions of respiration; *third*, they are exposed to a temperature of from 98° to 104°; *fourth*, they are exposed to the action of the saliva, mucus of the mouth, œsophagus, and gastric juice. This last fluid is slightly viscid, but it consists of a considerable proportion of water, of mucus, of salts, the base of which is soda and ammonia, and of the lactic acid of Berzelius.

With respect to the nature of the aliments, we have already seen how variable they are, inasmuch as all the immediate principles of animals and vegetables, may be carried to the stomach, in different forms and proportions, for the formation of the chyme. Can we, therefore, when we take into consideration the nature of the aliments, and the circumstances under which they are placed in the stomach, account for the phenomena which are known to accompany the formation of the chyme? The particular temperature, the pressure, and the agitation which the aliments undergo, cannot be considered as essential causes of its transformation into chyme; it is probable that they merely assist in the production of this effect. There remain, therefore, the action of the saliva, and of the peculiar fluid secreted by the stomach. But, from the known properties of the saliva, it is incredible that it can attack and change the nature of the aliments, though it may serve the purpose of diminishing the cohesion of their particles. We must, therefore, attribute this remarkable effect, to the fluid formed by the internal membrane of the stomach. It appears, then, that this is the agent which acting chemically on the alimentary substances, dissolves them from the surface towards the centre.

To establish, incontrovertibly, this point, it has been attempted to produce what has been called, since the time of Reaumur and Spallanzani, *artificial digestion*. For this purpose, after having masticated the food, it has been mixed with the gastric juice, and afterwards exposed in a tube, or other vessel, to the same temperature as that of the stomach. Spallanzani has asserted that they succeeded, and that aliments were reduced to chyme. But since the more recent researches of M. Montegre, it appears to be shewn that this is not the case, but, on the contrary, that the substances employed, did not undergo any alteration, at all analogous to that of chymification, which agrees with the experiments of Reaumur. But even if the gastric juice does not dissolve the aliments with which it is enclosed in a tube, we cannot therefore conclude, with some, that this fluid does not dissolve the aliment, when it is introduced into the stomach. The circumstances are far from being the same. In the stomach, the temperature is equal; the aliment pressed and agitated; the saliva and gastric juice renewed continually; and, as soon as the chyme is formed, it is forced into the duodenum. There is nothing of all this takes place, when the aliment is placed in a tube, or a vessel, and then mixed with the gastric juice. The want of success, therefore, in artificial digestion, proves nothing with respect to the formation of chyme.

How then, it may be asked, can the same fluid act in a similar manner upon a great number of different substances, varying essentially from each other? The character of acidity which enables it to act upon albumen, for example, would seem to render it incapable of dissolving fatty substances. But to this it may be replied, that it has not been proved that the gastric juice is always the same. The small number of analyses which have been made prove, on the contrary, that its properties vary considerably. It is possible, that the contact of different aliments with the mucous membrane of the stomach may have an influence upon its composition; it is certain, at any rate, that it differs in different animals. That of man, for example, is incapable of attacking the tissue of the bones, while the dog digests these substances perfectly.* In general, the action by which the chyme is formed, prevents the reaction of the constituent elements of the food upon each other; but this is only true when the digestion is good. It is found, when the powers of digestion are impaired, that fermentation, or even putrefaction, may take place. There seems reason to believe, that the great quantity of inodorous gas, which is thrown off, in some cases, and the sulphuretted hydrogen which is disengaged in others, is attributable to this cause.

* We should be careful, however, lest we admit too much, as respects those conjectured variations of the animal fluids. The more perfect the science of chemical analysis becomes, the more constant we find the composition of vegetable and animal substances to be.

For a long time the nerves of the eighth pair have been supposed to preside over the act of chymification. If, indeed, we divide or tie these nerves at the neck, the substances introduced into the stomach undergo no further alteration. The inferences, however, which have been drawn from this fact, do not seem to be strictly just. May we not confound the effects of deranged respiration upon the action of the stomach, with the direct influence of the section of the nerves of the eighth pair upon this organ? I am tempted to believe that this is the case; for if we divide the eighth pair of nerves in the thorax, below where the branches are given off to the lungs, the aliment which is afterwards introduced into the stomach, is transformed into chyme, and furnishes abundant chyle. Some persons have supposed, that electricity* has some influence in the production of chyme, and that the nerves, of which we have been speaking, act as conductors. There is no positive fact to justify this conjecture. A more probable use of the nerves of the eighth pair is, that they establish intimate relations between the stomach and the brain, by which the presence of injurious substances in the aliment is indicated.

In a person whose health is good, the formation of the chyme takes place without his being conscious of it; he only perceives that the sense of fulness and slow respiration, produced by the distention of the stomach, by degrees, disappear. But in persons of a delicate constitution, digestion is very frequently accompanied with an indisposition to mental effort and a general sense of coldness, with slight chills and drowsiness. It has been said, that the vital powers, at this time, are concentrated upon this organ, and that there is a temporary neglect of the rest. To these general effects, may be added the production of gas, which escapes by the mouth, a sensation of weight, warmth, dizziness, and at other times of burning about the stomach, with a similar sensation along the œsophagus, &c. These effects are particularly felt towards the termination of chymification, but it is not always found that slow digestion is attended with injurious effects.

* Since the publication of this work, this doctrine may be considered fully established by the experiments of Dr. Wilson Philip and Mr. Brande, &c. See note, p. 93.

Action of the small Intestine.

This is the longest portion of the canal, and establishes a communication between the stomach and large intestines. It is incapable of great distention, has numerous convolutions, and is very long. It is attached to the vertebral column by a fold of the peritoneum, which allows of free motion, but at the same time limits it. Its longitudinal and circular fibres are not separated, as in the stomach; its mucous membrane, which presents numerous villosities and a large number of mucous follicles, forms folds, irregularly circular, the number of which increases, as we examine the intestines, near the pyloric orifice; these folds are called *valvulæ conniventes*. The small intestines are very vascular; and their nerves arise from ganglions of the great sympathetic. The lacteal vessels open upon its internal surface by very numerous orifices.

This intestine has been divided into three parts, which are distinguished by the names of *duodenum*, *jejunum*, and *ilium;* a distinction but of little use in physiology. Like the mucous membrane of the stomach, the small intestines secrete an abundance of mucus; I do not think it has ever been analysed. I have found it to be viscid, of a saltish taste, and to change the vegetable purple colours red; all the properties which we have before noticed in the fluid secreted by the stomach. Haller gave to this fluid, the name of *intestinal juice;* it has been estimated, that eight pounds of this fluid is formed in twenty-four hours. At a short distance from the pyloric orifice of the stomach, is found the common orifice of the biliary ducts, and the pancreatic duct, by which the fluids secreted by the liver and pancreas, pass into the cavity of the intestine. If the formation of the chyme is still a mystery, the nature of the phenomena which take place in the small intestines, is by no means better understood. We shall confine ourselves still to the plan which we have adopted; that is, we shall content ourselves with describing what observation has proved to us. We shall first speak of the introduction of the chyme into the small intestines, and afterwards of the alterations which it undergoes there.

Accumulation, and Passage of the Chyme into the small Intestines.

I have often had occasion to observe in dogs, the chyme passing from the stomach into the duodenum. The following are the phenomena which I have remarked. At intervals, more or less remote, we see a contractile motion take place towards the middle of the duodenum; this is rapidly propagated towards the pylorus; this ring, itself, contracts, as well as the pyloric portion of the stomach. In consequence of this movement, the substances contained in the duodenum, are thrust towards the pylorus, where they are stopped by the valve; and those which are contained in the pyloric portion of the stomach, are forced towards the cardiac. But this motion directing the intestine towards the stomach, is soon replaced by a motion in the opposite direction; which is propagated from the stomach, towards the duodenum, and which forces from the pylorus a certain quantity of chyme. It appears to me then, that the valve of the pylorus serves the purpose, both of preventing the substances contained in the small intestines from flowing back into the stomach, and also, of retaining the chyme and the aliments in the cavity of this organ.

This motion is repeated, generally, several times in succession, varying in the frequency and intensity of the contractions; after which it ceases for some time. It is not very distinctly marked when the formation of the chyme begins, as the extremity only of the pyloric portion partakes in it. It augments as the stomach becomes empty, and towards the end of chymification I have frequently seen the whole of this organ partake in the action. I have ascertained that this motion is not suspended by the division of the nerves of the eighth pair. When the chyme has entered into the small intestines, the motion ceases. In proportion as it is repeated, the chyme becomes accumulated in the first portion of the small intestines, it distends a little their walls, spreading itself over the intervals of the *valvulæ conniventes.* Its presence soon excites the organ to contract, and, by this means, a part is thrown further into the intestine, and the rest remains attached to the surface of the membrane, and takes soon after the same direction. The same phenomenon is continued into the large intestines; but as the duodenum receives new portions of chyme, at a certain period in the process, the small intestines are filled with this matter through their whole extent. We observe, however, that it is much less abundant in the neighbourhood of the cœcum, than at the extremity of the pylorus.

The motion which impels the chyme through the small intestines, has a very great analogy to that of the pylorus. It is irregular, returns after unequal periods, is made sometimes in one way, and sometimes in another; and is manifest often in several parts at the same time. It is always slow, and alters the relations of the intestinal circumvolutions, and it is entirely free from the control of the will. We should form very incorrect ideas on this subject, if we confined ourselves to the examination of the small intestines in an animal recently killed. It displays then a degree of activity far greater than during life. But in persons with impaired digestion, it acquires an activity and energy not generally observed during health. Whatever may be the manner in which this motion is executed, the progress of the chyme through the small intestines is very slow; the numerous valves already noticed, the many asperities projecting from the surface of the mucous membrane, and the multiplied curvatures of the canal, must all have the effect of retarding its progress, but must favour its admixture with the fluids contained in the intestine, and the production of the chyle which results from it.

Change which the Chyme undergoes in the Small Intestines.

The chyme is not changed in its sensible properties until it arrives at the orifice of the *ductus communis choledochus*, and the excretory duct of the pancreas. Thus far, it preserves its colour, semi-fluid consistence, sharp odour, and slightly acid taste; but, on being mixed with the bile and pancreatic juice, it acquires new characters. Its colour becomes yellowish, its taste bitter, and its sharp odour essentially diminished. If it consist of animal or vegetable substances, containing fat or oil, there will be seen to form, here and there upon its surface, irregular filaments, flattened or rounded, which attach themselves to the surface of the valvulæ conniventes, and appear to be imperfectly formed chyle. We do not remark this, when the chyme consists of aliments which do not contain oil. There is also a greyish coat, that adheres to the mucous membrane, which appears to be the elements of the chyle. The same phenomena are observed in the two superior thirds of the small intestines; but in the inferior third, the chyme acquires a greater degree of consistence; its yellow colour assumes a deeper tint; and it often becomes, at last, of a greenish brown, which pierces through the intestinal walls, and gives to the ilium an appearance different from the duodenum and jejunum; when the cœcum is examined, we shall find whitish striæ; these appear to be nothing more than the residue of the substances which have served for the formation of the chyle.

From what has been said of the varieties which the chyme exhibits, it will be perceived, that the changes which it undergoes in the small intestines, must vary, according to its properties. Indeed the phenomena of digestion in the small intestines vary, with the nature of the aliment.* The chyme, however, preserves its acid property, and if it should happen to contain fragments of aliments, or other substances which have resisted the action of the stomach, these pass through the small intestines without undergoing any change. The same phenomena take place, when the same substances are employed. I have recently satisfied myself of this, by examining the bodies of two criminals, who, two hours before their execution, had eaten the same kind of food in nearly equal quantities. The substances contained in the stomach, the chyme in its pyloric portion, and in the small intestines, appeared to me precisely similar in consistence, colour, taste, and odour, &c.

It is rare that we do not meet with gas in the small intestines, during the fermentation of the chyle. M. Jurine, of Geneva, was the first person who examined this subject with attention, and pointed out the nature of the gases; but at the period that this learned physician wrote, eudiometrical processes were far from having acquired the degree of perfection, at which they have since arrived. I was, therefore, induced to make some new experiments on this interesting subject. M. Chevreul assisted me in executing this undertaking. Our experiments were made on the bodies of two criminals, opened a short

* We have made many experiments on this subject, but it would have been improper to have detailed them in a work professedly elementary.

time after death, and who, having been young and vigorous, were extremely favourable to these researches. In one, twenty-four years of age, who had eaten two hours before execution, bread and cheese, and drank red wine, we found in the small intestines,

Carbonic acid,	24.39
Hydrogen,	55.53
Azote,	20.08
Total,	100.00

In a second subject, twenty-three years of age; who had eaten of the same food at the same time, and who had been executed at the same time, we found,

Carbonic acid,	40.00
Hydrogen,	51.15
Azote,	8.85
Total,	100.00

In a third experiment, made upon a young man, twenty-eight years of age, and who had eaten four hours before his execution, bread and beef, and lentils, and drank red wine, we found in the small intestines,

Carbonic acid,	25.00
Hydrogen,	8.40
Azote,	66.60
Total,	100.00

We have never observed any other gas in the small intestines. This gas may be produced in different ways; it may either come from the stomach, with the chyme; it may be secreted by the mucous membrane of the intestines; it may be produced by the reciprocal action of the substances contained in the intestine; or perhaps, it may arise from all these three causes combined. The stomach, however, contains oxygen, with very little hydrogen; while in the small intestines, we have uniformly met with a considerable portion of hydrogen, but no oxygen. Daily observation shews also, that whenever the stomach contains gas, it is discharged by the mouth, towards the end of chymification, probably, because at this time, it most readily passes into the œsophagus. The secretion of gas by the mucous membrane, is not known to take place, except carbonic acid gas, which appears to be performed in this manner during respiration.

With respect to the reciprocal action of the substances contained in this intestine; I have often observed air bubbles to escape rapidly from the chyme. This phenomenon has taken place from the orifice of the *ductus communis choledochus*, to the commencement of the ilium, but no trace of it can be perceived in this intestine, nor in the superior part of the duodenum, or stomach. I have made this observation on the body of a criminal, four hours after death; it did not present any trace of putrefaction. The alteration that the chyme undergoes in the small intestines, is unknown; it is evident, that it is the result of the action of the bile, pancreatic juice, and of the fluid secreted by the mucous membrane; but what is the precise nature of the affinities exerted in this operation, which may be considered truly chemical, and how the chyle comes to be precipitated upon the surface of the *valvulæ conniventes*, while the surplus remains in the intestine, to be at last thrown out of the system; is a question of which we are completely ignorant. We know but little of the time required for the chyme to be sufficiently altered; but it does not take place very rapidly. In animals, three or four hours after eating, it often happens that we do not find that the formation of the chyle has taken place.

From what has been said, it will be seen, that the chyme in the small intestines, is divided into two parts. The one is attached to the walls, and is the chyle in an imperfect state; the other is destined to be pushed into the large intestines, and at last entirely rejected. Thus is accomplished, that most important part of digestion, the production of chyle.

Action of the large Intestines.

This organ is of considerable extent; it passes over a long circuit, between the right iliac region where it commences, and the anus where it terminates; it is divided into *cœcum*, *colon*, and *rectum*. The cœcum is situated in the right iliac region, and is connected with the small intestines. The colon is subdivided into an ascending portion, which extends from the cœcum to the right hypochondrium, a transverse portion, which passes horizontally, from the right to the left hypochondrium, and a descending portion, which is prolonged to the cavity of the pelvis. The rectum is very short; it begins where the colon finishes, and terminates in the anus.

The large intestine is bound down by folds of the peritoneum; disposed so as to allow of variations in its volume. Its muscular coat has a peculiar arrangement. Its longitudinal fibres form three narrow bands, very distant from each other when the intestine is dilated. Its circular fibres, also, are formed into bands, much more numerous, but also separated. The result is, that at a great number of points, the intestine is only formed by the peritoneum and the mucous membrane. These places are generally arranged into distinct cavities, where the fecal matter accumulates. The rectum alone, does not exhibit this structure, its muscular coat is very thick and uniform, and appears to contract with great energy.

The mucous membrane of the large intestine is not, like the small intestine, covered with *villi*, but is, on the contrary, smooth, its colour of a pale red, and we find on it but few follicles. At the place of its junction with the small intestines, there is found in the cœcum, a valve, evidently intended to allow substances to pass into this intestine, but to prevent their return into the small intestine; there is a smaller number of arteries and veins distributed to this organ, than to the small intestines; the same remark also applies to the nerves and lymphatics.

Accumulation and Passage of the Fecal Matter into the large Intestines.

By the contraction of the inferior portion of the ilium, the matter contained in it is made to pass into the cœcum. This motion is very irregular, and returns at distant intervals. It is seldom remarked in living animals, but may be frequently seen in those which are killed suddenly. It does not, in any way, resemble the action of the pylorus. In proportion as this motion is repeated, the matter contained in the ilium becomes accumulated in the cœcum. It cannot return into the small intestines, in consequence of the valve of the cœcum, and can only pass through the opening which communicates with the colon. Having once passed into the cœcum, it receives the following names; *fecal*, or *stercoraceous matter*, *fœces*, and *excrement, &c.* After remaining sometime in the cœcum, the fecal matter passes into the colon, and traverses, successively, its different portions;

sometimes forming one continued mass, and sometimes forming distinct masses, which fill one or more of the cavities which the intestine presents, through its whole length.

The progress of the fecal matter is, almost always, very slow; it is effected by the contraction of its muscular fibres, and the pressure which the intestine suffers, as one of the abdominal viscera; and it is favoured, also, by the mucous secretion of its internal membrane. Having arrived at the rectum, the matter accumulated there distends its walls, and forms, often, a mass of several pounds; it cannot pass beyond this, as the anus is habitually closed by the contraction of the two sphincter muscles. The consistence of the fœces in the large intestine is very variable, but, in a person in good health, it is always greater than in the small intestines. Generally, its consistence increases as it approaches the rectum, but it is made softer by the fluids which the mucous membrane secretes.

Changes of the Fecal Matter in the large Intestines.

Before penetrating into the large intestine, this matter does not exhibit the fœtid odour, peculiar to the human excrement; but it contracts this odour, however short the time it remains there. Its colour, a brownish yellow, becomes also deeper, but, with respect to consistence, odour, colour, &c. there are many varieties, according to the nature of the food, the manner in which chymification and chylification have been performed, the peculiar constitution of the individual, or the state of his health during the preceding digestion; there is found in the excrement all those substances, which have not been changed by the action of the stomach, we often find there stones of fruit, grain and other substances. Many celebrated chemists have analysed the human feces. M. Berzelius found them composed of,

Water,	73.3
Vegetable and animal remains,	7.0
Bile,	0.9
Albumen,	0.9
Peculiar extractive matter,	2.7
Matter formed from bile, resin, animal matter, &c.	14.0
Salts,	1.2
Total,	100.0

These analyses, made with the intention of throwing light on the mysterious nature of digestion, afford us but feeble assistance. In order to give us any considerable advantage, it would be necessary to have the circumstances very much varied; to know exactly the nature and quantity of food that had been used, to keep in view the constitution of the individual, and to analyse only the fœces which had been formed from very simple alimentary substances. But an undertaking of this kind supposes a degree of perfection in our means of analysis, at which animal chemistry has not yet arrived.

There exists also in the large intestines, gases, enclosed with the fecal matter. M. Jurine long since determined their nature, but he has only made one satisfactory experiment on this subject. In the large intestines of a drunken person, found frozen to death, and opened as soon as convenient, he ascertained the existence of azote, carbonic acid, carburetted and sulphuretted hydrogen. M. Chevreul and myself, examined with care, the gas found in the large intestine of those criminals of whom we have before spoken. In the subject of the experiment first cited, the large intestine was found to contain in a hundred parts of gas,

Carbonic acid,	43.50
Hydrogen carbon, and some traces of sulphuretted hydrogen,	5.47
Azote,	51.03
Total,	100.00

The subject of the second experiment, exhibited, in the same intestine.

Carbonic acid,	70.00
Hydrogen, and carburetted hydrogen,	11.06
Azote,	18.94
Total,	100.00

In the subject of the third experiment, we analysed separately the gas found in the cœcum and the rectum, the following are the results:

Cœcum.

Carbonic acid,	12.50
Hydrogen,	7.50
Carburetted hydrogen,	12.50
Azote,	67.50
Total,	100.00

Rectum.

Carbonic acid,	42.86
Carburetted hydrogen,	11.18
Azote,	45.96
Total,	100.00

Some traces of sulphuretted hydrogen were manifested on the mercury before this gas was analysed.

These results, which may be depended on inasmuch as every precaution was taken to prevent error, agree very well with those that had been made long before by M. Jurine; but they invalidate his assertion respecting the carbonic acid, the quantity of which, according to this physician, diminished from the stomach to the rectum; but we see on the contrary, that the proportion of this acid increases as you go from the stomach. The same doubts which we express respecting the origin of the gas in the small intestines, may be applied to that produced in the large. Is it received from the small intestine, or is it secreted by the mucous membrane, or formed by the reaction of the constituent principles of the fecal matter, or does it arise from this triple source? It is not easy to remove these doubts.

We may however, remark, that this gas differs from that in the small intestines. In this last, hydrogen predominates, while in the large intestines it does not exist, but instead of it, carburetted and sulphuretted hydrogen.

I have seen besides, frequently, gas passing out in the form of innumerable small bubbles, from the substance contained in the large intestine.

From what has been said, we may conclude, that the action of the large intestines is of little importance in the production of the chyle. It fulfils, sufficiently well, the office of a reservoir, where are deposited, for a certain time, the residue of the chemical operations of digestion, to be afterwards expelled. I conceive that the digestion is completely effected without the large intestines taking any part of it. Nature presents this disposition in those individuals, who have an artificial anus, which passes out at the cœcal extremity of the small intestine, and from which those substances escape that have assisted in the formation of the chyme.

Expulsion of the Fecal Matter.

The principal agents in the expulsion of the fecal matter, are the diaphragm and abdominal muscles; the colon and rectum co-operate, but, generally speaking, not in a very efficient manner. As long as the fecal matter is not accumulated in the large intestines, especially in the rectum, we are not conscious of its existence; but when it is collected in this part, in considerable quantity, it distends the rectum and produces a vague sensation of fulness and uneasiness, over the whole abdomen. This sensation is soon replaced by another, much more vivid, which gives us notice of the necessity of voiding the fecal matter. If this notice be neglected, it often ceases for a considerable time; at others, the sensation is too urgent to be resisted, and the excrement must be discharged, notwithstanding all our efforts to prevent it. The consistence of the fecal matter has an influence upon the vivacity of this sensation. It is almost impossible to resist it, if this matter be very fluid, but it is easily overcome when the contents of the rectum are hard.

There is nothing easier to comprehend than the mechanism of the expulsion of the excrement. In order that this may be effected, all that is required is, that the fecal matter accumulated in the rectum, should be pushed forward with a force superior to the resistance which the muscles of the anus present. The contraction of the rectum alone, cannot produce this effect; notwithstanding the great thickness of its muscular coat, it is necessary that some other power should co-operate. This is effected partly by the diaphragm, which acts directly from above, downwards, upon the whole mass of the abdominal viscera, and by the abdominal muscles, which press them against the vertebral column. From these combined forces, there results a considerable pressure, which forces forward the stercoraceous matter collected in the rectum; the resistance of the spincters is overcome; they relax, and the matter contained in the rectum, is voided by the anus. But as the cavity of the rectum is much more spacious than the opening of the anus, which has a constant tendency to contract, the matter passing out through this opening will be moulded to its size and form. It will pass the more readily, when its consistence is little, but when the reverse is the case, great force is required to expel it. When it is very fluid, the contraction of the rectum alone, seems sufficient for this purpose.

A phenomenon analogous to what we have noticed in the œsophagus, has been observed in the rectum by M. Halle. This learned professor has remarked, that during the efforts to void the fecal matter, the internal membrane of the rectum is displaced and forced down, so as to form a sort of hood near the anus. This effect must, in a great measure, be produced by the contraction of the circular fibres of the rectum.

The desire of voiding the excrement returns after different intervals, according to the quantity and nature of the aliments employed, and the constitution of the individual; generally, it does not take place until after several consecutive meals. In some persons, it takes place once or twice in the twenty-four hours; but in others, who still enjoy good health, this evacuation does not take place oftener than once in ten or twelve days. Habit is one of the causes, which has most influence on the regular return of the excretion of the fecal matter. When this habit is established, it returns, with great exactness, at the same hour. Many persons, particularly females, are compelled to have recourse to artificial means, as *enemata*, &c. to assist them in performing this function.

The expulsion of the gas is not periodical. Its progress is much more rapid and irregular. Its displacement being very easy, it arrives very soon at the anus, by the peristaltic motion of the large intestine only. It is, however, often necessary for the abdominal walls to contract, in order to expel it. But the expulsion of gas *per anum*, is neither regular nor constant. In many persons, this but rarely takes place, while in others, it is very frequent. The use of certain aliments has an influence upon its formation; its production, to any considerable extent, is considered as indicating a bad digestion.

With the expulsion of the fecal matter, this complex function, the end of which is the formation of the chyle, is accomplished. But we should have fulfilled our task very imperfectly, if, according to the example of many distinguished authors, we should limit ourselves to treating of the digestion of aliments.

There is another consideration which presents itself for our investigation; this is the digestion of liquid aliments, or drinks.

Of the Digestion of Drinks.

It is very remarkable that, though physiologists have devoted much time to investigating the digestion of solid aliments, have invented systems to explain it, and experiments to illustrate it, yet they have never given any attention to the digestion of drinks, although the subject presents less apparent difficulty. Drinks are generally much more simple than solid aliments, and are, for the most part, nourishing and easily digested. The circumstance that we digest drinks, should have been considered alone, sufficient for rejecting the systems of trituration and maceration. Indeed, we see that drinks can neither be bruised, nor macerated, though they remove hunger, restore vigour, and in a word, *nourish* the body.

Of the Prehension of Drinks.

The prehension of drinks may be executed in a variety of ways; but Petit has shown that they may be referred to two principal modes.* In the first, we pour the drink into the mouth, which is effected by the specific gravity of the fluid. Our common way of drinking must be referred to this mode, when we raise the vessel to our lips, and place them in contact with it, and pour the fluid into the mouth. The action of *gulping*, which consists in pouring into the mouth the whole contents of the glass; and drinking *à la régalade*, in which the head is thrown back, the jaws separated, and the fluid poured into the mouth in a continued stream, belong also to this mode. In the second we cause a vacuum to take place in the cavity of the mouth, the pressure of the atmosphere, at the same time, forcing the fluid to penetrate into it; as for example, in the act of *sipping* or *sucking*. When we intend to *sip* a fluid, it is executed in the following manner; the mouth is applied to the surface of the fluid, we then enlarge the chest, by which the pressure of the atmosphere upon the portion of the surface of the fluid intercepted by the lips is diminished, and the fluid, therefore, rises into the place of the air which has been drawn from the mouth.

* Vide Memoires de l'Academie des Sciences. Années, 1715 16.

In the act of *sucking*, the mouth resembles an air pump, the *opening* of which is formed by the lips, the *body* by the cheeks, palate, &c., and the *piston* by the tongue. We apply the lips accurately about the body, from which we intend to extract the fluid, the tongue being also in contact with it; the tongue then contracts itself, by which it is carried backwards, and its volume diminished; a vacuum is thus formed between its superior surface and the palate; the fluid contained in the body which we suck, being compressed unequally by the atmosphere, is displaced, and fills the mouth. Neither mastication, nor saliva being required for the digestion of drinks, it is not necessary that they should remain long in the mouth; they are, therefore, swallowed as soon as they are received. They undergo no other change in passing through this cavity, but that of temperature. If, however, the taste be strong or disagreeable, or, if finding it agreeable, we are desirous of prolonging the pleasure, the presence of drink in the mouth, then causes a discharge of saliva to take place, which is mixed with the fluid.

Of the Deglutition of Drinks.

We swallow fluids in the same manner as solid aliments; but as fluids glide more easily over the mucous membrane of the palate, tongue and pharynx, and as they yield readily to the slightest pressure, they therefore possess all the qualities which are required for passing rapidly through the pharynx, and are generally swallowed with much less difficulty than solid aliments. I know not why the contrary opinion so generally prevails. It is supposed that the particles of fluids, having a constant tendency to separate, must present a greater degree of resistance to the action of the organs of deglutition; but daily experience disproves this opinion.

Any one may easily prove upon himself, that it is easier to swallow fluid than solid aliments, even after they have been fully masticated, and impregnated by the saliva.* We may call the portion of aliment, swallowed during each motion of deglutition, a *morsel*. These vary much in volume, but, however large they may be, when they consist of fluids, they accommodate

* The manner in which deglutition is performed during disease, may be alleged as a proof of this. In severe inflammation of the throat, the patient can only swallow fluids.

themselves readily, to the form of the pharynx and œsophagus, and therefore never produce any painful distention of these passages, as is often observed to take place from solid aliments. In the common method of drinking, the deglutition of fluids exhibits the three stages, of which we have before spoken, except in *gulping*, or drinking *à la régalade*, when the fluid is poured directly into the pharynx, and the two last stages only take place.

Of the Accumulation of Drinks in the Stomach, and of the time they remain there.

They differ little in this respect from solid aliments. Their action is generally more prompt, more equal, and easier; probably because the fluids spread themselves, and distend the stomach more uniformly. Like the solid aliments, they occupy more particularly the left and middle portion of the stomach, the right or pyloric portion seldom containing much fluid. The distention of the stomach by fluid cannot be carried, suddenly, to a great extent, because it will be rejected by vomiting. This accident frequently happens to persons who swallow, in a short period, a large quantity of drink. When a person who has taken an emetic wishes to hasten vomiting, there is no better method of effecting this, than by swallowing suddenly several glasses of fluid. The presence of drink in the stomach produces effects, similar to those which we have described under the article, *Accumulation of Aliments*. The same changes in the form and position of the organ, the same distention of the abdomen, the same obstruction of the pylorus, and contraction of the œsophagus are observed in both.

The general phenomena are different from those which are produced by the solid aliments. This arises from the action of the fluids upon the walls of the stomach, and the promptitude with which they are carried into the blood. The fluids passing more rapidly through the mouth and œsophagus, than the solid food, preserve more perfectly their original temperature, when they arrive in the stomach. It arises from this, that we prefer fluids, when we wish to produce in this organ a sensation of heat or cold; and it is for this reason, that we give a preference in winter to warm drinks, and in summer to cold ones. It is well known, that drinks remain a much shorter time in the stomach, than the solid aliments, but the mode in which they pass out from this viscus, is but imperfectly understood. It is generally believed, that they traverse the pylorus and pass into the small intestines, from which they are absorbed with the chyle. When a ligature, however, is passed around the pylorus, so as to prevent their passing into the duodenum, it does not essentially retard their disappearance from this cavity. We shall insist more on this important point, when we come to speak of the absorption of drinks.

Alteration of Drinks in the Stomach.

In this respect, drinks may be divided into two classes; first, those which do not form chyme; and, second, those which are capable of being either wholly, or partially converted into this substance. To the first class may be referred pure water, alcohol sufficiently diluted to be considered as a drink, and the vegetable acids, &c. When water is received into the stomach, its temperature soon becomes equalized with that of the surrounding viscera; and, at the same time, it becomes mixed with the mucus, saliva, and gastric juice, which are found in this organ, by which it becomes turbid, and soon disappears, without undergoing any perceptible change; it partly passes into the small intestines, and is, in part, directly absorbed. After its disappearance, there remains a certain quantity of mucus, which is soon reduced into chyme. We know from observation, that water deprived of atmospheric air, as distilled water, or when it is charged with considerable quantities of salts, as well water, remains long in the stomach, producing there a sensation of weight. Alcohol acts in a very different manner. We at first perceive a sensation of warmth, which it impresses as it passes along the mouth, pharynx, and œsophagus, which it likewise excites in the stomach, as soon as it arrives there. The effects of this action are to contract the organ, to irritate the mucous membrane, and augment the secretions of which it is the seat; at the same time, it coagulates all the albuminous parts of the alimentary substances with which it is in contact; and, as the different fluids which are found in the stomach, contain a large quantity of this matter, the result is, that, in a short time after we have swallowed alcohol, there is, in this viscus, a large quantity of concreted albumen. The mucus undergoes a modification analogous to that of the albumen; it becomes hard, and forms irregular elastic filaments, which preserve a slight degree of transparency.

In producing these phenomena, the alcohol becomes mixed with the water contained in the saliva and gastric juice, it dissolves, probably, a part of the elements which enter into their composition, so that it must become weakened by remaining in the stomach. Its disappearance is extremely sudden, and its general effects are also very rapid, drunkenness or death following, almost immediately, the introduction of a large quantity of alcohol into the stomach. The substances which have been coagulated by the action of the alcohol, are, after its disappearance, digested like solid aliments.

Among the drinks which are reduced into chyme, some are only changed in part, while others are entirely transformed into this substance; oil is an example of this; it is changed, in the pyloric portion of the stomach, into a substance very analogous to that which is obtained after the purification of oils by the sulphuric acid;—this substance is evidently the chyme of oil. In consequence of this transformation, oil remains, perhaps, longer than any other fluid in the stomach.

It is well known that milk becomes coagulated, shortly after it is swallowed. This coagulum is then a solid aliment, which is digested in the ordinary way. Milk and water can only be considered as a drink. The greater number of drinks which we use, are formed of water or alcohol, in which are suspended, or held in solution, the immediate principles of animals and vegetables; as gelatin, albumen, osmazome, sugar, gum, fæcula, and colouring, or astringent substances. These drinks contain salts of lime, soda, potash, &c. By the results of many experiments which I have made upon animals, and some observations that I have collected upon man, I have ascertained, that there takes place in the stomach, a separation of the water, or alcohol, from those substances, which these fluids held in solution. These last remain in the stomach, where they are transformed into chyme, like aliments, while the alcohol, or water, with which they were united, is absorbed, or passes into the small intestines. In a word, they act in the manner we have just described, in speaking of water and alcohol. Those salts which are held in solution by the water, do not abandon this fluid, but are absorbed with it.

Red wine, for example, becomes turbid soon after it is swallowed, from its mixture with those secretions, which are formed by, or carried into the stomach. It soon coagulates the albumen of these fluids, which thus become filled with *flocculi;* afterwards, its colouring matter, disengaged perhaps by the mucus and albumen, is deposited upon the mucous membrane. At any rate, we see a certain quantity in the pylorus; the aqueous and alcoholic part disappear very suddenly. Soups undergo similar changes; the water which they contain is absorbed, while the gelatin, albumen, fat, and probably the osmazome, remain in the stomach, and are reduced into chyme.

Action of the Small Intestines upon Drinks.

From what has been said then it appears, that drinks penetrate into the small intestines under two different forms, viz: first, that of a fluid; second, that of chyme. Except under particular circumstances, the fluids which pass from the stomach into the intestines remain but a very short time there. They do not undergo any other alteration, than admixture with the chyme, pancreatic juice, bile, and other secretions of these organs. There is no chyle formed from them, but they are generally absorbed in the duodenum, or commencement of the jejunum, being rarely seen in the ilium, and still more seldom in the large intestines. Indeed, this last circumstance seldom happens, except in diseases; during the action of a cathartic, for example.

The chyme which is produced by drinks follows the same course and seems to undergo the same changes as that of the aliments. Such are the principal phenomena of the digestion of drinks; we must perceive the propriety of considering them separately from the digestion of solid aliments. But they are not digested separately, this vital operation is often carried on at the same time, on both classes of aliments. Drinks seem to favour the digestion of the solid aliments; it is probable that they produce this effect in a variety of ways. They soften and dissolve certain aliments, and aid, in this way, their chymification and their passage through the pylorus. Wine acts in a similar manner, especially on those substances which it is capable of dissolving; it excites also by its contact, the mucous membrane of the stomach, causing an increased secretion of the gastric juice. The action of alcohol strongly resembles that of wine, varying chiefly in intensity. The principal effect produced by taking *liquors* after dinner, is an increased excitement of the stomach.

Remarks upon the Deglutition of Atmospheric Air.

Independently of the faculty of swallowing fluid, and solid aliments, many persons are capable of introducing air into the stomach by deglutition. It was long supposed that this faculty was very rare. M. Gosse, of Geneva, being the only person, publickly known, who possessed this faculty to any considerable degree. I have, however, since ascertained, in a work on this subject, that it is far from being uncommon.* In a hundred students of medicine, I found eight or ten who possessed it. In the same work I have shown, that we may divide those persons who are capable of swallowing air into two classes. Those who do it with great facility, and those who only succeed after great efforts. When persons of the last description wish to do this, they in the first place expel the air from the chest, as far as possible; they then fill the mouth with air; so as to distend the cheeks, and execute deglutition, bringing the chin towards the chest, and then suddenly drawing it away. The action is similar to that of a person with a sore throat, who swallows with difficulty. With respect to those persons who are incapable of swallowing air, who constitute the great majority of mankind, I may observe, that, from experiments upon myself, and a great number of students of medicine, I have found that, with little practice, almost any one can do this, without great difficulty; for my own part, I succeeded after trying a few days. If there should be any good reason for believing that swallowing air would be useful, as a remedy in disease, there can be little doubt that patients could be easily taught to do it.

In the stomach, the air becomes warmed and rarefied, and soon distends the organ. In some persons, it excites a sensation of

* Memoir on the deglutition of atmospheric air, read before the Institute.

burning heat, in others it causes a desire to vomit, or even sharp pain. It is probable that its chemical composition becomes altered, but there is nothing positively known on this subject. Its continuance in the stomach is various, generally it returns through the œsophagus, and passes out by the mouth. At other times it traverses the pylorus, spreads through the whole extent of the intestinal canal, and at last passes out *per anum.* In this last instance, it distends the whole abdominal cavity, imitating the disease called *tympanitis.* I have remarked, in certain diseases, that the patients swallowed large quantities of air without appearing to be conscious of it. A young physician, a friend of mine, whose digestion is habitually bad, finds considerable relief from swallowing, occasionally a mouthful of air.

Remarks on Regurgitation, Eructation, and Vomiting, &c.

We have already seen that the contraction of the œsophagus prevents the substances contained in the stomach, and compressed by the abdominal walls, from returning into this canal. This however, sometimes takes place, when it receives the names at the head of this chapter, according to the extent to which it may be carried. The rejection of all the substances contained in the stomach is not effected with equal facility. Gas escapes more readily than liquids, and the last more easily than solid aliments. Generally speaking, the more the stomach is distended the more easily are its contents rejected by this organ. When it contains gaseous bodies, these necessarily occupy its superior part, and are, of course, in constant contact with the cardiac orifice of the stomach. On the slightest relaxation of this opening, especially when the stomach is strongly compressed, the gas passes into the œsophagus, and, if this tube offer no resistance, it arrives soon at its superior part, and escapes through the pharynx, causing the edges of this opening to vibrate; this is called *eructation.* It is probable, that the œsophagus, by moving in an opposite direction to that which is executed in deglutition, assists the discharge of the gas through the pharynx. When a quantity of vapour or fluid accompanies the gas which passes out of the stomach, it is called *cardialgia*, or *heartburn.* But it is not necessary that the air discharged in eructation, should come directly from the stomach; those persons who possess the faculty of swallowing air, can, after it has been forced through the pharynx, allow it to return. It is thus we may have a voluntary eructation, although, generally, this does not depend upon the will.

If instead of gas, fluids, or even small masses of solid food return from the stomach to the mouth, this phenomenon may be called *regurgitation.* This frequently happens in children, in whom the stomach is habitally distended by a large quantity of milk. It also frequently happens in persons who have eaten and drank very largely, especially when the stomach is strongly compressed by the contraction of the abdominal muscles, in making efforts to go to stool, for example. Although distention of the stomach is favourable to regurgitation; it is also, not rare to meet with individuals who discharge, every morning, one or two mouthfuls of gastric juice mixed with bile. This phenomenon is often preceded by eructations, which evacuate the gas, that the stomach also contains.

When this viscus is full, it is not probable that its contraction has much effect in forcing the substances which it contains, into the œsophagus; the abdominal walls are the principal agents in producing this. But when the stomach is nearly empty, it is probable that the motion of the pylorus has some agency in forcing the fluids into the œsophagus. This seems the more likely, as the fluids which are then rejected, are always, more or less, mixed with the bile; which cannot arrive in the stomach, without the contraction of the duodenum and pyloric portion of the stomach. It will be recollected, that the œsophagus contracts with but little energy when the stomach is empty In most individuals, regurgitation is entirely involuntary, and only takes place under particular circumstances; but there are some persons who can produce this at will, and thus remove from their stomach, the solid or fluid substances, which it contains. In observing them at the moment when they execute this, we shall see, they at first, make an inspiration, by which the diaphragm is depressed: they then contract the abdominal muscles, so as to compress the stomach; they often assist this action by pressing strongly with the hands the epigastric region; they remain in this position immoveable, when, suddenly, the fluid or aliment is found to ascend into the mouth. It may be presumed, that the time they remain immoveable, expecting the appearance of the substances in the mouth, is employed in producing a relaxation of the œsophagus, so that the substances which are enclosed in the stomach, may be introduced into it. If the contraction of the stomach has any effect in expelling these substances, it can only be considered, in a very remote degree auxiliary to it. This power of voluntary regurgitation, which some persons possess, is generally considered vomiting. There are some individuals, who after eating, take pleasure in causing the food to return to the mouth, to undergo a second mastication, and afterwards swallow it. Indeed they perfectly resemble, in this respect, that class of herbivorous animals which are said to *ruminate*.

Vomiting resembles the phenomena of which we have just been speaking, inasmuch as it has for its end, the expulsion of the substances contained in the stomach by the mouth. It differs, however, from these in some important respects; among others, from its being announced by a peculiar sensation; by the efforts which accompany it, and the fatigue with which it is always attended.

We give the name of *nausea* to that internal sensation which precedes vomiting; it consists in a general weakness, with a sense of uneasiness in the head, or in the epigastric region; the lower lip becomes tremulous, and the saliva is copiously poured out into the mouth. To this state succeeds, suddenly and involuntarily, convulsive contractions of the abdominal muscles, and, at the same time, of the diaphragm. The first are not very intense, but those which follow are much more so; at last they come to such a degree, that the substances contained in the stomach, overcome the resistance of the œsophagus, and are thus forced into the mouth. The same effect is produced frequently; it ceases afterwards, for a considerable time. I have remarked often, that animals, about the time they are vomiting, swallow a considerable quantity of atmospheric air. This air seems destined to favour the pressure that the abdominal muscles exert upon the stomach. It is probable, that the same phenomenon takes place in man.

At the moment, when the substances are driven from the stomach through the pharynx and mouth, the glottis becomes closed, the veil of the palate is raised, and becomes horizontal, as in deglutition. In the mean while, every time we vomit, there is introduced a certain quantity of fluid either into the larynx or nasal fossæ. It has been long supposed, that vomiting depends upon the sudden and convulsive contraction of the stomach; but I have shewn, in a series of experiments, that this viscus is almost entirely passive, and that the true agents of vomiting are the diaphragm on one part, and the large muscles of the abdomen on the other. I have even seen it produced, after substituting a pig's bladder for the stomach, which I filled with a coloured fluid.*

In the ordinary state, the diaphragm and abdominal muscles co-operate in vomiting, but they may, however, each produce it separately. For example, an animal continues to vomit, though the diaphragm be rendered immoveable, by dividing the diaphragmatic nerves. It also vomits after we have divided, with a bistory, all the abdominal muscles, if the precaution be taken of leaving the *linea alba* and peritoneum untouched I have never seen the stomach contract itself at the moment of vomiting; I conceive, however, that it is not impossible, that the movement of the pylorus is not seen at this instant. This was seen by Haller in two experiments, and it induced that illustrious physiologist to suppose, that the contraction of the stomach, was the essential cause of vomiting.†

Modification of Digestion by Age.

Authors generally represent the digestive organs as inactive during the fœtal state, and that at the period of birth, there takes place a sudden development of their powers, in order that they may be prepared to furnish the necessary materials, for the nutrition and increase of the body. If, by the term inactive, they mean

* See the details of these experiments, and the report of the committee of the institute, in my memoir on vomiting Paris, 1813.

† There has been a warm controversy on this question among the French physiologists. The doctrine here promulgated has been opposed, particularly by M. Bourdon, the principal ground of whose opinion is, a case of cancerous stomach, in which there was frequent nausea and unsuccessful efforts to vomit. M. Bourdon supposes that the reason why the patient did not vomit, was the diseased state of the stomach, by which it was rendered incapable of contracting. The objections of M. Bourdon have, however, been satisfactorily replied to by M. Piedagnel, and the doctrines of Magendie confirmed by numerous cases and experiments. See Journal de Physiologie Juillet, 1821.—*Trans.*

that the digestive organs of the fœtus do not act upon aliments, there can be no doubt of their correctness; but if they wish to be understood to the full extent of the expression, i. e. that they are *absolutely inactive*, I think they are mistaken. It is very probable, that there takes place in the organs of digestion, in the fœtus, an action very analogous to that of digestion. But of this subject, we shall have occasion to speak more at large, when we come to treat of the functions of the fœtus. The same remarks may be applied to the supposition, that the digestive system is not fully *developed*, at the period of birth. If we speak of the organs contained within the abdomen, it is evident, that they are proportionally more voluminous than at a more advanced age. But if it be asserted, that the whole digestive apparatus is not so perfect as it afterwards becomes, the remark must be acknowledged to be true; because the organs of prehension, mastication, and excretion of fecal matter, are far from possessing, at birth, the degree of perfection which they afterwards acquire. We cannot suppose that the energy of the abdominal organs, can supply the defects of those, of which we have been speaking; this is so far from being the case, that it is necessary that the food of infants should be very delicate, and easy of digestion; that which is peculiarly adapted to its organs, is the mother's milk; when it is deprived of this we all know how difficult it is to find any thing that will supply its place. Instead, therefore, of considering the digestive organs of new-born infants, or even of young children, as endowed with great power, we must consider them as much weaker than at a later period. If the digestive apparatus of children must be considered, as in some respects, less perfect than in the adult, nevertheless, there can be nothing more admirably adapted to the general purposes which it is destined to fulfil.

Suction is the mode of prehension suitable to infants, and the parts which perform this, are peculiarly fitted for the purpose. The tongue is large, in comparison with the whole volume of the body; the absence of the teeth allows the lips to be projected forward, to a considerable distance, and to embrace, more exactly than can be done by the adult, the *papilla* or *nipple*, from which the milk is extracted. During the first year, the infant is entirely destitute of the organs of mastication; the jaws are small, there are no teeth, the lower jaw is not curved, and does not present the same angle as in the adult; the elevator muscles, which are the principal agents in mastication, are inserted very obliquely. A sort of pad, formed chiefly of the gums, supplies the place of the teeth.

Towards the end of the first year, and in the course of the second, the first or milk teeth pass out from the alveolar processes, and garnish the jaws. Their irruption takes place with considerable regularity, in pairs. The two middle incisors of the lower jaw, generally, first display themselves, then the two superior, and successively, and in the same order, the lateral incisors, canine and small molares;* though the last do not often appear until the third year. At the age of four years, four new teeth appear, these are the first large molares; they complete the number of twenty-four, which the child preserves until it is seven years of age. At this period, the irruption of the second teeth takes place. The first or milk teeth, then fall out, generally, in the order they appeared, and are successively replaced by those teeth which are destined to remain through life. At this time, four large *molares* appear, which make twenty-eight teeth. Between the age of twenty and twenty-five, though sometimes much later, four more teeth appear, which are the *sapient teeth*, and the number of thirty-two teeth, proper to man, is then completed. This renewal of the teeth at the age of seven years, is necessary, from the increase which the jaws undergo. The milk teeth being small those which succeed them are larger, and denser in texture; their roots are longer and more numerous, and they are attached more firmly in the alveolar processes; arrangements indispensable to the functions which they are destined to fulfil.

At the same time that the jaws increase in size, they change their form. The inferior jaw is curved, its branches becoming more vertical, its body assumes a horizontal direction, and the angle is more distinctly marked. When the teeth first pass out from the alveolar processes, and the instrument is entirely new, the incisors have a sharp cutting edge, the canine teeth are pointed, and the face of the molares covered with sharp conical asperities; but in these respects they become somewhat altered with age. The teeth rubbing continually against each other, during mastication, or from being in contact with bodies more or

* Sometimes the first small molares come out before the canine.

less hard, have their form modified by the friction. We may form some idea of the age of a person by his teeth, but it is so rare that the teeth are disposed with perfect regularity, and possess an equal degree of density, that this can only be remotely approximated. Generally, the effect of using the teeth is first visible in the inferior incisors; it is seen afterwards in the molares, but much later in the teeth of the superior jaw. But the effect of use upon the teeth is, by no means, the most unfavourable change produced by age. In the first stage of dotage, they are forced from the alveolar processes by the progress of the ossification of the jaws, they thus become loose, and at last fall out. The manner in which this takes place is not regular, as happens in the first teeth, but varies in individuals.

Those who do not lose their teeth, until the period of which we are speaking, must be considered as privileged persons; for, generally speaking, they fall out much earlier, either by accidents, such as blows, or falls, which fracture or tear them out; or in consequence of the contact of air, or those substances which are habitually introduced into the mouth, by which their texture becomes altered, they exhibit spots, change their colour, become softened, and, at last, fall into fragments. These alterations are, improperly enough, called, *diseases of the teeth;* it is evident, however, that they are chemical changes, as artificial teeth are found to undergo the same process. After the teeth have fallen out, the gums become harder, and the alveolar cavities closed up; an arrangement which, in some sort, supplies the deficiency of the teeth.

Such are the modifications which the organs of mastication undergo with the progress of age; those which take place in the other digestive organs, are not of sufficient importance to require being particularized. We shall finish this article by remarking, that those voluntary muscles which assist in digestion undergo, in consequence of age, the same changes which we have already pointed out, in speaking of the modifications produced by this cause, in muscular contractions.

Our knowledge respecting the modifications of digestion in different ages, is very limited; our information on this subject is chiefly confined to the prehension and mastication of aliments, and the excretion of fecal matter; the changes which those parts of the digestive organs, which are contained in the abdomen, undergo, are nearly unknown. Hunger seems to be a very acute sensation in children, and does not return periodically, as in adults; it returns so often that it seems to be continual, and it frequently appears to exist when the stomach is far from being empty. Sucking is a mode of prehension peculiar to infants, and it is readily executed by them, from the extent of their lips and tongue. This action, at least for the first month, appears to be entirely instinctive. Until the appearance of the teeth, and even after dentition has begun, mastication is impracticable. If the infant compress those substances which are placed in its mouth, it is rather to extract the juice which they contain, or to favour their solution, than an attempt at mastication. It may, perhaps, be, that the excessive quantity of saliva in infants, supersedes, to a certain degree, the necessity of mastication.

It is necessary to pass to a consideration of the excretion of fecal matter, in order to be able to say any thing positive concerning the digestion of young infants, when compared with that of man at the adult age. The excretions of infants are much more frequent than at a more advanced age; they are almost always quite fluid, of a yellowish colour, and do not possess the peculiar odour which they afterwards assume, when other aliments than milk are eaten. The abdominal muscles, probably, do not possess sufficient energy at this age, to expel solid fecal matter.

The appearance of the incisor, and even of the canine teeth, are of but little assistance to the infant, in the function of mastication. It is necessary that the irruption of the molares should take place, in order that the action should be efficient; even after this has occurred, they cannot be exerted upon substances which offer any considerable degree of resistance; because the elevator muscles of the lower jaw are too weak, and are inserted too obliquely, to allow the teeth to act with much power, upon substances possessing a considerable degree of density. It is not until the second dentition, and even some time after, when the angle of the jaw has become well marked, that mastication acquires all the perfection of which it is susceptible. It remains in this state, unless modified by use, or the accidental loss of the teeth, until old age. At this period of life, it is generally found, that nearly all of the teeth have fallen out, and the person then masticates with the alveolar edge of the jaw. To these causes, which render mastication difficult in old age, may be added; first, the great extent of the lips, which, as soon as the teeth have fallen out, are longer than is necessary, to extend from one jaw to another, and which, therefore, touching by their internal surfaces, instead of having their edges in contact, are incapable of retaining the saliva. Second, the diminution of the angle of the jaw, which in this respect resembles that of infants; and the curvature of the body of this bone, which compels old men to chew with the anterior and middle part of the alveolar edge, the only parts where these edges meet. Third, the absence of the teeth, induces a necessity of chewing with the lips in contact, which gives, therefore, a peculiar character to the mastication of persons in this situation.

The action of the muscles which concur in digestion, undergo the same changes, as we have already pointed out, in speaking of the influence of different ages upon muscular contraction. Feeble in the infant, active and vigorous in youth and manhood, the muscles lose their energy in old age. The digestive actions, which depend upon muscular contraction, run the same round, as any one may satisfy himself, by examining the manner in which the prehension, mastication and excretion of fecal matter take place, at the different periods of life. Some old persons are habitually constipated, in consequence of the debility of the muscles. It has sometimes happened, that persons have been absolutely incapable of expelling the excrement; in consequence of which, it has become accumulated in the large intestine to an enormous extent, so that it becomes necessary to have recourse to a surgical operation.

We know, but in a very general way, the modifications which the stomach and intestines undergo, at the different periods of life. They appear to be more active during the increase of the body, and afterwards to become more sluggish in their action. But of all the vital actions, these preserve, until the last moments of life, the greatest degree of energy. We shall not enter here upon the consideration of the modifications, which arise in this function from sex, climate, habits, temperament, or the constitution of the individual. These considerations are no doubt interesting, but they more particularly belong to *hygeine;* we shall therefore limit ourselves to observing, that digestion varies in almost every individual, and that, even in the same person, it is rare that digestion does not undergo some change daily, so that a person may digest a substance to-day, and yet be absolutely incapable of doing this on a similar substance to-morrow.

Connexion of Digestion with the Functions of Relation.

A function so important as digestion, and for the performance of which so many different organs co-operate, must necessarily be intimately connected with the other functions, especially those of relation. This connexion exists, indeed it is even so intimate, that in most animals, a knowledge of one or more of the organs of external life, enables us to form a correct judgment of the disposition of the digestive organs; and, on the contrary, by inspecting one part of the digestive apparatus, we can form a very just idea of the arrangement of the organs of sense and voluntary motion.

The senses point out to us the presence of aliments; they assist us in seizing them, make us acquainted with their physical and chemical properties, and their beneficial or injurious qualities. As it is especially in this last respect, that it is of importance for us to appreciate aliments, we may consider the senses of smell and taste, which perform this office, as having more intimate relations with digestion, than the other senses; some authors, indeed, have classed them among the digestive actions.

It is often the case, that the aspect and odour of food excites the appetite, and prepares the organs of digestion for the discharge of their office. The reverse, however, is sometimes the case, i. e. it entirely removes all desire of food, and produces a sensation of disgust. Generally speaking, a moderate appetite imparts to the senses more delicacy and activity; but, as we have seen above, when hunger is prolonged, the senses become impaired, so as at last to transmit only imperfect impressions. During chymification, they have also less activity, especially if the stomach be much distended with food. The relations of muscular contraction with digestion, are not less evident. We have already shewn, that the action of the muscles assists in the prehension, mastication, and deglutition of the aliments, and the excretion of the fecal matter; besides this, they transport the body to procure food, they excite the appetite by their action, and, when their efforts are great, they require an abundant nourishment. In their turn, they are influenced by digestion; hunger debilitates them, and impairs their motions; and, on the contrary, when the stomach is full, especially in warm climates, and persons in delicate health, there is great indisposition to motion. But in cold countries, and in robust individuals, the presence of food in the stomach, increases their vigour and agility.

We may easily explain the difficulty which is felt in singing or speaking, after a generous repast. The volume of the stomach prevents the introduction of air into the chest, and the motions of the diaphragm, and thus offers an obstacle to the production of the voice. The relation between the functions of the brain and the organs of digestion are particularly intimate. Hunger forcibly directs the thoughts to the means of obtaining aliment; and, on the other hand, strong mental excitement, violent chagrin, or sudden fright, often take away the appetite, and stop the powers of digestion for some days; so that aliment which had been before introduced into the stomach, remains without undergoing any alteration. Nothing is more common than to see persons, whose minds are oppressed by gloomy affections, in whom the functions of digestion are completely perverted. Contentment and gaiety of spirits, on the other hand, favour digestion; great eaters are seldom subject to mental depression. Every one must have noticed the influence which digestion exerts upon the operations of the mind; many persons are absolutely incapable of making any mental effort during digestion; the accumulation of fecal matter in the large intestines, has a still more marked influence upon the moral affections.

COURSE OF THE CHYLE.

It would be useless for the digestive organs to form chyle, if this fluid afterwards remained in the intestinal canal. It is, therefore, necessary that the chyle should be transported from the small intestines into the venous system. This is the end of the function which we are now about to examine. To preserve, as far as possible, the method by which we have thus far been guided, in the exposition of the functions, we shall first speak generally of the chyle.

Of the Chyle.

We may consider the chyle in two different points of view. First, when it is mixed with the chyme in the small intestines, and when its characters are such as we have described, in speaking of the phenomena of its formation. Second, under the form of a fluid, moving in the chyliferous vessels, and thoracic duct. No one having, particularly, investigated the properties of the chyle, during the time it remains in the small intestines, our knowledge on this point does not extend beyond what has been already said on this subject, in speaking of the action of this intestine in digestion. On the other hand, the fluid chyle contained in the chyliferous vessels has been examined with great care.

The best method of procuring this fluid is, to give food to an animal, and, when a sufficient time has elapsed for the digestion to be going on in its fullest activity, to either strangle the animal, or to divide the spinal marrow behind the occipital bone. We must then lay open the chest, through its whole extent, and pass a ligature, which shall embrace the aorta, œsophagus, and thoracic duct, as near as possible to the neck. By turning back the ribs on the left side, we shall then see the thoracic duct, lying along side of the œsophagus; we then detach this at its upper part, wiping it carefully to remove the blood, and, by puncturing the duct, we may permit the chyle to run into the vessel which is intended to receive it.

The ancients were acquainted with the existence of the chyle, but entertained very incorrect ideas concerning it. At the beginning of the seventeenth century, considerable attention was directed to this subject. It was found to be of a white colour and opaque, and was therefore compared to milk, and the vessels which contained it were called *lacteals;* a very incorrect name, inasmuch as there is no resemblance between the chyle and milk, except in colour. It is only of late, and chiefly by the labours of Dupuytren, Vauquelin, Emmert, and Marcet, that we have acquired positive ideas of the chyle. We shall state the observations of these distinguished men, adding those which we have made ourselves.

If the animal from which the chyle is extracted had eaten of fatty animal, or vegetable substances, the fluid drawn from the thoracic duct, will be of a white milky appearance, rather heavier than distilled water, of a spermatic odour, stimulating the tongue, a little saltish, and perceptibly alkaline. Soon after having passed out from the vessel, in which it was lodged, the chyle runs into a mass, and acquires a consistence almost solid; after some time, it separates into three parts; one solid, which is found at the bottom of the vessel, another fluid which is found above it, and a third, which forms a sort of pellicle on the surface of the fluid; the chyle, at the same time, assumes a bright reddish tint. When it consists of aliments which do not contain fat, its general properties are the same; but, instead of being white and opaque, it is semi-transparent, and the pellicle, formed on the surface, is less distinctly marked than in the first kind of chyle. The chyle never assumes the colour of those colouring substances which are mixed with the aliments, as some authors have asserted. M. Halle ascertained this by direct experiments. I have recently repeated these experiments, with precisely the same results. After causing animals to eat indigo, saffron, and madder, I have inspected the chyle, but never found that its colour seemed to have any relation to these substances.

Of the three parts into which the chyle separates, when left to itself, that on the surface of an opaque, white colour, is a fatty substance; the coagulated, or solid part, is formed of fibrine and a little red colouring matter; the fluid is analogous to the serum of the blood. The proportion of these three parts varies, according to the nature of the aliments. There are various chyles; for example, that of sugar, which contains but very little fibrine; and that of flesh, which contains much more. The same remark applies to the fatty part, which is extremely abundant, when the aliments contain fat or oil, while this is hardly distinguishable, when the aliments are destitute of fat. The same salts which are found in the blood, exist also in the chyle. We shall give some further details relative to the chyle hereafter.

Of the Apparatus of Absorption and the Course of the Chyle.

This apparatus is composed, first, of those absorbent vessels peculiar to the small intestines, which are called the lacteals; second, the Mesenteric glands; third, the Thoracic duct.

The *lacteal vessels* are extremely small, and very numerous. They arise from imperceptible orifices on the surface of the villosities of the mucous membrane of the intestine, and extend to the mesenteric glands, in the substance of which they seem to be lost. In the walls and on the surface of the small intestines, they are extremely delicate and numerous. They inosculate freely, so as to form a fine and beautiful reticulated structure, an arrangement which is especially visible when they are filled with white and opaque chyle. They enlarge in size, and diminish in number, as they go from the surface of the intestine, and at last form insulated trunks, which extend to the neighbourhood of the mesenteric arteries, and sometimes in the intervals which separate them, it is in fact in this form that they reach the mesenteric glands.

We give the name of *mesenteric glands*, to the small, irregularly formed, lenticular bodies, which are found before the vertebral column, between the two laminæ of the peritoneum, called the *mesentery*. Their dimensions vary from two or three lines to an inch; they are very numerous. But little is known of their structure; they receive a large number of blood vessels, in proportion to their size, and are endued with great sensibility. Their parenchyma is of a pale rose colour, and their consistence not very great. On compressing them between the fingers, we extract a transparent, inodorous fluid, which has never been chemically examined. It is especially abundant in the centre of these bodies. I have observed a remarkable quantity of it in the bodies of criminals. The sanguineous and lacteal vessels found in these glands, are reduced into tubes of extreme tenuity, so that we are unable to trace the precise relation they bear to each other. It is however, certain, that injections forced into either, traverse the gland with the greatest facility. There arise from the mesenteric glands, a great number of vessels of the same nature as the lacteals, but in general larger. These are the roots of the thoracic duct. They are directed towards the vertebral column, and run along with the *aorta* and *vena cava*. They anastomose frequently, and terminate in the *thoracic duct*.

The name of *thoracic duct* is given to a vessel, of the same kind as those which we have just described. It is about the size of a goose quill, and reaches from the cavity of the abdomen, where it commences, to the left subclavian vein, where it terminates. In its course, it passes between the pillars of the diaphragm by the side of the aorta; it then runs along the vertebral column until it arrives opposite to the left subclavian vein, when it turns off and terminates in that vessel. It sometimes opens into both subclavian veins, and sometimes into the right alone. In the interior of the thoracic duct and lacteal vessels, are found valves, so arranged, as to permit the chyle to pass towards the left subclavian vein, but to prevent its moving in an opposite direction; true valves, however, are not always found. The walls of the lacteal vessels and thoracic duct are composed of two distinct membranes, the one internal, thin, and formed into folds, which constitutes the valves. The external coat is fibrous, and possessed of a greater power of resistance than would have been anticipated from its great tenuity.

Before explaining the phenomena of absorption, and the course of the chyle, it will be proper to make a few observations on the organs which contain it. After twelve, twenty-four, or even thirty-six hours of abstinence, the lacteal vessels of a dog will be found to contain a small quantity of semi-transparent fluid, of a slight milky tint, and which exhibits other properties analogous to those of the chyle. This fluid which is met with in the lacteal vessels, and thoracic duct, and which has never been analysed, appears to be chyle, formed from the digestion of the saliva and mucus of the stomach. This seems the more probable, as the causes which increase the secretion of these fluids, as acid drinks, diluted alcohol, &c. increase its quantity. When the animal is deprived of nourishment for three or four days, the lacteal vessels get into the same condition as the lymphatics; being sometimes filled with lymph, and at others perfectly empty. From these facts, then, it is evident, that the chyle of aliments, which is extracted by the lacteals, is always either mixed with the chyle of digested mucus or with the lymph; the result is the same, if we extract the chyle of the thoracic duct, which is constantly filled with lymph, even after eight or more days of abstinence. The substance which has been examined by chemists under the name of chyle, is far from consisting entirely of the extract of the alimentary substances; it is evident that it constitutes only a given proportion of it.

Absorption of the Chyle.

It cannot be doubted, that the chyle passes from the cavity of the small intestines into the lacteal vessels. How then, it may be inquired, is this effected? It would seem at a first glance, to be easy to explain so simple a phenomenon. But this is not the case. It has already been remarked, that the situation of the mouths of the lacteal vessels is not known, nor is there any thing better known of their mode of action, though many persons have undertaken to explain it. This has sometimes been attributed to the capillary attraction of the orifices of the vessels, and the compression of the chyle upon the walls of the small intestines, &c. Of late it has been attributed to a peculiar sensibility in the mouths of the absorbents, and the organic insensible contractility, with which they are supposed to be endued. We can hardly imagine how men of distinguished minds can either propose or admit such explanations. For my own part, they appear to be a plain and simple acknowledgment of our ignorance of the nature of this phenomenon. There is one fact relating to this subject, which it will not be useless to mention; it is that absorption continues to go on for a considerable time after death. After having emptied one or more of the lacteal vessels, in an animal recently dead, by compression, we shall again see it, in a short time, filled up anew. We may repeat this experiment several times in succession. I myself have done it, after the animal has been dead for two hours.

Course of the Chyle.

We have already described the course of the chyle. It at first passes through the lacteal vessels, traverses the mesenteric glands, arrives at the thoracic duct, and is then poured into the left subclavian vein.

The causes which give it motion are, the peculiar contractility of the lacteal vessels, the unknown cause which produces absorption, the pressure of the abdominal muscles, especially in the motions of respiration, and, perhaps, the action of the arteries of the abdomen. If we wish to form a just idea of the rapidity with which the chyle runs along the thoracic duct, it will be only necessary to do, as I have frequently done, viz. to open this canal in a living animal, at the part where it forms a junction with the left subclavian vein. We shall find then, that its rapidity is not very great, but that it is increased every time the animal compresses the abdominal viscera, by the contraction of the abdominal muscles; we may produce a similar effect by compressing the belly with the hand.

It has always appeared to me, that the rapidity with which the chyle circulates through its vessels, is proportioned to the quantity which is formed in the small intestines. This depends upon the quantity of chyme; so that if the aliments are abundant, and easy of digestion, the chyle will pass along quickly. If, on the contrary, the aliments are small in quantity, or, what amounts to the same thing, if they are difficult of digestion, as there will be little chyle formed, its progress will be slow. It would be difficult to estimate, accurately, the quantity of chyle formed during any given digestion; it is, no doubt, however, considerable. In a dog of an ordinary size, but who had eaten as much animal food as he chose, from an incision made in the thoracic duct in the neck, the animal being still alive, there passed out more than half an ounce of this fluid, in five minutes, and it continued to ooze out as long as the chyle was formed, that is, during several hours.

I do not know, if in the course of the same digestion, the progress of the chyle varies in rapidity; but, if we suppose it uniform, it will be perceived, that there must enter into the venous system, six ounces of this fluid in one hour. In man, where the chyliferous organs are more voluminous, and where digestion is performed much faster than in the dog, we may presume, that the proportion of chyle is much more considerable. The blood which passes through the subclavian vein, cannot penetrate into the thoracic duct, because there exists at its orifice, a valve so disposed as to prevent this. For the same reason, in consequence of the valves in the thoracic duct, and lacteal vessels, the chyle cannot flow back towards the intestinal canal.

Almost all physiologists have supposed, that the chyle undergoes some peculiar alteration in traversing the mesenteric glands. Some have suspected, that these bodies produce a more intimate admixture of the component parts of the chyle; others have thought that they add to it a fluid intended to render the chyle more liquid; there are others again, who imagine, on the contrary, that they take away something from the elements of the chyle, in order to purify it. The truth is, we are entirely ignorant of the influence which the mesenteric glands exert upon this fluid. In the same way, much has been said of the variable qualities of this fluid; according as the digestion is good or bad The decay, which takes place in some diseases, has been attributed to the formation of a bad chyle, owing to the nature of the aliments. But indeed, we know very little of the modifications which take place in the composition of the chyle. Much has been said also of certain parts of aliments, which pass, with the chyle, into the blood, without being altered by the digestive organs. But this is mere conjecture, without a single positive experiment to support it.

Dr. Marcet,* who has recently analysed the chyle, has compared that formed from animal substances, with that of vegetables; he found, that the last contained three times as much carbon, as the chyle produced from the animal food. We learn from Professor Dupuytren's very ingenious researches, that

* Annales de Chimie, 1816.

the thoracic duct is the only route by which the chyle passes, to serve the purposes of nutrition.

We know from the experiments of Duverney, in some cases of obstruction of the thoracic duct; and especially from the experiments of Flandrin, of which we have spoken in another place; I say, we know, on these authorities, that the thoracic duct may cease to pour the chyle into the vein, at the point where it terminates, without producing death. We know, it is true, that, in some cases, a ligature upon this canal has produced death, though we were then ignorant of the causes of these different results; but the experiments of M. Dupuytren have given a satisfactory explanation of them. This expert surgeon, passed a ligature about the thoracic duct of several horses, some of them died in the course of five or six days, while others preserved every mark of perfect health. In those animals which died from the effects of the ligature, it was always impossible to force any injection from the lower part of the duct into the subclavian vein; it is very probable, therefore, that the chyle ceased to be poured into the venous system, after the application of the ligature. On the contrary, in those animals which survived, he always found it easy to make mercurial injections pass, and even other substances, from the abdominal portion of the duct into the subclavian vein. The matter injected, followed the duct into the vicinity of the ligature; there it turned aside, and entered some large lymphatic vessels, which opened into the subclavian vein. It is then evident, that in these animals, the tying of the thoracic duct had not prevented the chyle from mixing with the venous blood.

Inasmuch as the lacteal vessels absorb the chyle, and carry it into the venous system, it has been assumed, that they fulfil the same office for all those substances which are mixed with the aliments, and which, without being digested, pass into the blood. Authors have generally said, for example, that drinks are absorbed with the chyle; but, as they have not shown this to be the case by a single experiment, we may reject the opinion, on this ground alone, as doubtful.—I have endeavoured to satisfy my own mind on this point, by direct experiments on living animals, but I have not met with a single instance in which I could detect the drink mixed with the chyle. When a dog is made to swallow a quantity of diluted alcohol, during the digestion of solid aliments; if, in half an hour afterwards, the chyle be extracted, in the manner I have already pointed out, it will be found that this fluid does not contain alcohol, while the blood smells strongly of it, and when distilled gives over this substance. We obtain similar results by giving a solution of camphor, or any other odorous fluid.

The modifications which take place in the absorption and course of the chyle, in different ages, has never been investigated; we only know, that the mesenteric glands change their colour, diminish in volume, and are at last nearly obliterated, in old age. Some authors have supposed, that they do not suffer the chyle to pass through them; but this seems to be a mere bold assertion, unsupported by any well authenticated facts. We are also completely ignorant how far sex, temperament and habits, modify this function; nor are we better informed respecting the relations which exist between this function, and those which we have already explained, or which remain for us to examine.

ABSORPTION OF THE LYMPH.

We have just seen how much remains to be done, in order to give precision to our ideas of the absorption, and course of the chyle; but *this Function*, a history of which we are now about to give, is still more imperfectly understood. We know generally that it exists, but we have scarcely a remote conception of its utility in the animal economy. Its apparent object is to pour the lymph into the venous system. It may be presumed that this phenomenon constitutes but one point in its utility; nevertheless, when we come to define the limits of our knowledge, it is confined to this alone.

Of the Lymph.

Nothing shews more strikingly, the imperfection of our knowledge of this function, than the different opinions which have been entertained by physiologists, of the nature of the lymph. Some have given this name to the serum of the blood, others to the fluid which is seen on the serous membranes, and others again to the serosity of the cellular tissue, while some have considered the fluid which oozes from certain scrophulous ulcers, as lymph. For ourselves, we intend to confine the meaning of the term lymph, to the fluid which is contained in the lymphatic vessels and thoracic duct. It is the more necessary to attach a fixed meaning to this word, because, by admitting other significations, we consecrate as true, opinions, than which nothing is further from being demonstrated; namely, that the fluids of the serous membranes, cellular tissue, &c. are absorbed by the lymphatic vessels, and transported by these vessels into the venous system.

To procure lymph, we may have recourse to two processes. The one consists in laying bare a lymphatic vessel, puncturing it, and collecting the fluid which passes out. But this operation is difficult to execute, as the lymphatic vessels are not always filled with lymph. The other process consists in suffering an animal to fast, during four or five days, and then to extract the fluid contained in the thoracic duct, in the manner we have mentioned in speaking of the chyle. The fluid which is obtained by either of these methods, is of a reddish colour, and opaque. It has a distinct spermatic odour, a saline taste, and sometimes exhibits a decidedly yellowish tint, while at others, it is of the colour of madder. I think it important to insist on these details, because a neglect of them, has probably induced errors in the experiments which have been made upon the absorption of colouring matter. But the lymph does not remain long in a fluid state, it soon forms itself into a mass; its red colour assumes a deeper tint, numerous reddish filaments become developed in an irregular, arborescent form, very analogous to the vessels found in the tissue of the organs. When we examine with care, this mass of coagulated lymph, we perceive that it is formed of two parts; the one of which is solid, consisting of numerous cells, containing the other part, which is fluid; if we separate the fluid part, it again runs into a mass.

The quantity of lymph which can be collected in this manner, from a single animal, is very inconsiderable, we can obtain from a large sized dog, scarcely, an ounce and an half. It has appeared to me, that the quantity increased, as the fast is prolonged. I think also, that I have observed that its colour becomes redder, when the animal has been long deprived of food. The solid part of the lymph, which may be called its coagulum, has a great analogy with that of the blood. It becomes of a scarlet red, when it is brought in contact with oxygen gas, and of a purplish red when it is plunged into carbonic acid gas. Its specific gravity, when compared with distilled water, is :: 1022.28 : 1000.00. I requested M. Chevreul to analyse the lymph of a dog. I gave to him a considerable quantity, which I had procured, in the manner mentioned above, after having caused the animal to fast for several days. The following are the results obtained by this distinguished chemist. A thousand parts of lymph contained,

Water,	926.4
Fibrine,	004.2
Albumen,	061.0
Mur. soda,	006.1
Carbon. soda,	001.8
Phosph. lime and magnesia, Carbon. lime,	000.5
Total,	1000.0

Apparatus of Absorption, and Course of the Lymph.

There is a strong analogy in the disposition and structure of this apparatus, and that for the absorption and course of the chyle; or rather, except in an anatomical point of view, they form parts of the same system. This apparatus is composed of lymphatic vessels, glands, or lymphatic ganglions, and the thoracic duct; which we have already mentioned in speaking of the course of the chyle. The lymphatic vessels exist in almost every part of the body. They are small, anastomose frequently and have the same reticulated arrangement every where. In the extremities they form two planes, the one superficial, and the other profound. The first is placed in the cellular tissue, between the skin and the aponeurosis beneath; in general it accompanies the sub-cutaneous veins. When the vessels which form this plane are filled with mercury, and the injection has succeeded well, they represent a network, which surrounds with its meshes the whole of the limb. The deep seated lymphatics of the limb are seen, principally, in the intervals between the muscles, and about the nerves and large vessels.

Both the superficial and deep seated lymphatics, as they pass towards the superior part of the limb, diminish in number, increase in size, and terminate soon in the lymphatic glands of the groin, arm-pits, and anus, &c. from whence they pass either into the abdomen, or chest. In the trunk, the lymphatics form, in the same manner, two laminæ, the one sub-cutaneous, the other placed on the internal surface of the walls of the visceral cavities. Each viscus has also two orders of lymphatics, the one occupying the surface, and the other appearing to arise from the substance of the organ. It has been in vain attempted to trace these vessels in the brain, spinal marrow and their envelops, the eye, and the internal ear, &c. The lymphatic vessels of the trunk and extremities accompany the thoracic duct; but those from the external parts of the head and neck, terminate in the following manner, viz. those of the right side in a large vessel, which opens into the right subclavian vein, and those of the left side into a similar vessel, somewhat smaller, which opens into the left subclavian vein, a little above where the thoracic duct discharges itself.

We are ignorant of the disposition of the lymphatic vessels at their origin. Many conjectures have been made on this subject, all equally destitute of foundation. That which seems to be the most plausible is, that they arise by extremely fine roots from the substance of the membranes, and cellular tissue, and the parenchyma of the viscera, where they appear to be continued to the last ramifications of the arteries. It often happens, that an injection forced into an artery, passes into the lymphatics of the part to which it is distributed.

In their course, the lymphatics exhibit no regularity, they increase or diminish in volume, they are sometimes rounded or cylindrical, and sometimes they present a number of swellings near to each other. Their structure does not, sensibly differ from the lacteal vessels; like them they are garnished with valves. In man, each lymphatic vessel, before arriving at the venous system, must traverse a lymphatic gland. But this disposition does not exist in any other animals which have lymphatic glands. These organs are very numerous, and, in form and structure, entirely resemble the mesenteric glands; they are found particularly in the armpits, neck, about the lower jaw, beneath the skin of the nape of the neck, in the groin, and in the pelvis about the large vessels. The lymphatic vessels seem to bear the same relation to them, as the lacteal vessels do to the glands of the mesentery.

Of the Absorption of the Lymph.

In order that we may investigate, with advantage, the absorption of the lymph, it is indispensable to examine the ideas which are at present received respecting the origin of this fluid, and the absorbing faculty attributed to the radicals of the lymphatic vessels. It will be necessary for us in doing this to make use of great caution, and even sometimes of severity; for, independently of the peculiar difficulty of the subject, we shall have to discuss an opinion generally admitted to be true, and sustained by the most respectable authorities. But, as the only motive which animates us is a love of truth, not a fondness for innovation, we trust that no one will feel disposed to censure us for the part we shall take in this question.

Let us inquire at first respecting the supposed origin of the lymph.—According to the best authors, the lymph is the result of the absorption which the lymphatic vessels exert on the surface of the mucous, serous, and synovial membranes, the laminæ of the cellular tissue, the skin, and the parenchyma of each organ.

The above view comprehends two distinct ideas, *viz.* first, that the lymph exists in the different cavities of the body; and second, that the lymphatic vessels possess the faculty of absorbing it. Of these two ideas, the first is entirely incorrect, and the other deserves a particular examination. Indeed, although there is some analogy between the appearance of this fluid, and that which is found on the surface of the serous and synovial membranes, cellular tissue, &c.; yet we have already shown, that the lymph differs from these fluids, both in its physical and chemical characters. And as these different fluids vary among themselves, if we admit this origin of the lymph, it will necessarily consist of different kinds of fluids. Now the lymph has always been found to possess the same sensible qualities, in all parts of the body.

Let us next examine the faculty of absorption, which is attributed by authors to the lymphatic vessels. The fluids introduced into the stomach and intestines, are promptly absorbed; the same thing happens in whatever part of the body the fluid is thrown. The skin and the mucous membrane of the lungs possess also the same property. The ancients remarked many of these phenomena, but, being ignorant of the existence of the lymphatic vessels, supposed that the veins were the agents of absorption. This opinion was maintained until the middle of the last century, when the nature of the lymphatic vessels became better understood. William Hunter, who was one of the anatomists who have contributed most to our knowledge of these vessels, insisted most strongly, on their exclusive power of absorption. This doctrine was propagated, and even enlarged upon, by his brother and pupils, and, generally, by all those who have devoted themselves to the anatomy of the lymphatic vessels. It is necessary that the proofs upon which they founded their doctrine, should possess all the strength which they have attributed to them. In consequence of the importance of the subject, we propose entering into some details.

To establish that the lymphatic vessels possess the power of absorption, and that the veins are destitute of it, experiments have been made. But, even supposing them to be exact, which, as we shall hereafter see, is far from being the case, they are so few in number, that it is truly astonishing, that they should ever have been thought sufficient to overthrow a system, which had been so long and generally admitted. Of these experiments, some have been made to prove directly, that the lymphatic vessels absorb, and others, again, to show that the veins do not possess this power. We shall, for the present, occupy ourselves with the first, and shall examine the second, under the article *absorption of the veins.*

John Hunter, who was one of the first who positively denied the absorption of the veins, and admitted that of the lymphatics, performed the following experiment, which appeared to him very decisive of the question. He opened the belly of a dog, and emptied a portion of the intestines, of the matter which it contained. He then injected warm milk into it, which was retained by means of ligatures. The veins which belonged to this portion of the intestines, were emptied of their blood, by small punctures made into their trunks. The blood was prevented from going to them, by ligatures on the arteries which corresponded to them; in this situation the part was returned into the belly. He allowed it to remain for half an hour, and then drew it out; and, having examined it carefully, he found, that the veins were nearly as empty as when they were returned into the belly, and that they did not contain any white fluid, while the lacteals were quite full.* The imperfect state of the art of performing physiological experiments at that time, is the only apology for this celebrated anatomist, in not having perceived how many important circumstances there were wanting in this experiment, supposing it to be exact, to enable him to draw any consequences from it. Indeed, in order that this experiment should be of any value, it would be necessary to know if the animal was fasting when it was opened, or was then performing the function of digestion; it would have been necessary to have examined the state of the lymphatics at the commencement of the experiment, in order to have ascertained whether they were full of chyle; what changes took place in the milk during the time it remained in the intestine; upon what evidence he asserted that the lacteals were filled with milk, at the end of the experiment, or whether the fluid which they contained did not rather consist of chyle. This experiment has been repeated at different times, by Flandrin, professor in the Veterinary School of Alfort, a man justly celebrated for the accuracy of his experiments on living animals, without any success; that is, without having perceived milk in the lymphatic vessels. I have myself often repeated this experiment, and the results which I have obtained perfectly agree with those of Flandrin, and are, of consequence, opposed to that of Hunter.

Thus the principal experiment of a distinguished author, who is said to have seen other fluids than chyle absorbed by the lymphatic vessels, appears to be, if not an illusion, at least so imperfect, that no important inference can be drawn from it. The other experiments of John Hunter being still less conclusive than this, I have passed them over in silence. They have been unsuc-

* See Cruikshank's Anatomy of the absorbent vessels.

cessfully repeated by Flandrin, nor have I myself been more fortunate in attempting them.*

I have thought it worth while to endeavour to determine, whether the lacteal and lymphatic vessels of the intestinal canal absorb any other fluid, than that of the chyle. I, in the first place ascertained, that if a dog be made to swallow four ounces of pure water, or if it be mixed with a certain quantity of alcohol, or of colouring matter, acid, or salt, at the end of about an hour, the whole of the fluid will be absorbed from the intestinal canal. It is evident, that if these different fluids were absorbed by the lacteal vessels of the intestines, they would pass through the thoracic duct; if this were the case, we should find a considerable quantity of them in this duct, when we collect the lymph of these animals, a half or three quarters of an hour after introducing these fluids into the stomach.

Experiment First. A dog was made to swallow four ounces of a decoction of rhubarb; in half an hour afterwards, the lymph was extracted from the thoracic duct. This fluid did not present any trace of the rhubarb, although nearly half of the decoction had disappeared from the intestinal canal; the urine, however, perceptibly contained rhubarb.

Experiment Second. A dog was compelled to drink six ounces of a solution of the prussiate of potash in water; a quarter of an hour afterwards; the urine was found evidently to contain the prussiate; the lymph extracted at the same time from the thoracic duct, manifested no signs of it.

Experiment Third. Three ounces of alcohol diluted with water, were given to a dog.† At the end of a quarter of an hour, the blood of the animal exhibited a marked alcoholic odour; but in the lymph nothing of the kind was found.

Experiment Fourth. Having passed a ligature about the thoracic duct of a dog, near the neck, he was made to drink two ounces of a decoction of *nux vomica;* a liquid which is extremely poisonous to animals; the animal died as suddenly as if the thoracic duct had been left perfect. On opening the body, it was ascertained that the duct was not double, but that it terminated

* John Hunter employed but five animals in all his experiments upon absorption.

† Pure alcohol kills dogs almost immediately.

singly in the left subclavian vein; and that the ligature had been tightly drawn around it.

Experiment Fifth. A ligature was passed about the thoracic duct of a dog, and two ounces of a decoction of nux vomica injected into the rectum. The effects were similar to those which would have taken place, if the duct had not been tied; i. e. the animal died almost immediately. The structure of the duct was analogous to that in the preceding experiment.

Experiment Sixth. M. Delille and myself performed the following experiment upon a dog, which seven hours before had been allowed to eat a large quantity of food, in order that the lacteal vessels might be easily perceived. We made an incision into the abdominal walls, and drew out a fold of the small intestines, upon which we applied two ligatures, sixteen inches apart. The lacteals which arose from this portion of the intestine, were extremely white and distinct, in consequence of the chyle with which they were distended. Two new ligatures were placed upon each of these vessels, about four inches apart; and we then divided these vessels between the two ligatures. We satisfied ourselves also, by every possible means, that the fold of the intestines taken from the abdomen, had no communication with the rest of the body by lymphatic vessels. Five mesenteric arteries and veins were sent to this portion of the intestine. Four of these arteries, and the same number of veins, were tied and divided in the same manner that the lymphatics had been; afterwards, the two extremities of this fold of intestine, were divided, and entirely separated from the rest of the small intestines. Thus we had a portion of small intestine, about sixteen inches long, not communicating with the rest of the body, except by one mesenteric artery and vein. These two vessels were insulated about four fingers breadth in length. We removed even the cellular coat, lest lymphatics should be concealed in it. We then injected into this fold of intestine about two ounces of the decoction of the nux vomica, a ligature being applied to prevent the passing out of the injected fluid. The fold was then covered with a piece of fine linen, and replaced in the abdomen. In the space of an hour, or an hour and six minutes, the effects of the poison were manifested with their ordinary intensity; so that every thing took place as if the fold of intestine had been in its natural state.

I have often repeated each of these experiments, and have varied them in different ways, and have always found the same results. I think they are sufficient to show, positively, that the lymphatic vessels are not the only agents of intestinal absorption, and that they are at least sufficient to render doubtful, the opinion that these vessels absorb other substances than chyle. It is rather from analogy, than from positive facts, that it has been admitted, that lymphatic absorption takes place from the genito-urinary and pulmonary mucous surfaces, the serous and synovial membranes, the cellular tissue, the surface of the skin, and the substance of the organs. We intend, nevertheless, to examine the small number of proofs, by which they have been supported by authors. The lacteal vessels of the intestinal canal, are the only effective organs of absorption in this part; the lymphatic vessels then, of the rest of the body, which exhibit a similar arrangement to the lacteals, must possess the same power. Such is the reasoning of the partisans of lymphatic absorption; and, as it is known that all the external and internal parts of the animal economy absorb, it has been concluded, that the lymphatic vessels were the only instruments of absorption.

If the faculty of lymphatic absorption of other substances than chyle, from the intestinal canal, had been demonstrated, there would be much force in this reasoning.

But as we have already proved that there is nothing less certain than this, we cannot admit it, and we are obliged to recur to other facts, or experiments, which, as is generally believed, demonstrate lymphatic absorption.

In animals which had died in consequence of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and peritoneum filled with blood. He concluded, therefore, that these vessels absorbed the fluid with which they were filled. But I have often met, both in animals and in men, the lymphatics distended with blood, where there had been no extravasation of this fluid; besides, in some cases, there is so little difference between the lymph and the blood, that it will be difficult to distinguish them. The fact, therefore, of Mascagni, has no important bearing on the question.

John Hunter, after having injected water coloured with indigo into the peritoneum of an animal, said, that he saw the lymphatics, shortly afterwards, filled with a fluid of a blue colour; but this fact has been disproved by the experiments of Flandrin, upon horses. This author injected into the pleura, and the peritoneum, not only a solution of indigo and water, but other coloured fluids, but he never saw them in the lymphatics, though they were promptly absorbed. M. Dupuytren and myself, have made more than a hundred and fifty experiments, in which we have submitted a great number of different fluids to the absorption of the serous membranes, but we have never seen them, in a single instance, introduced into the lymphatic vessels. The substances which were thus introduced into the serous cavities, produced very sudden effects, from the rapidity with which they were absorbed. Opium produced drowsiness, and wine drunkenness, &c. I have satisfied myself, by many experiments, that tying the thoracic duct, does not diminish the promptitude, with which these effects manifest themselves.

It is very doubtful then, whether the lymphatic vessels are the organs which absorb, in the serous cavities. We may add, that the tunica arachnoides, the membrane of the aqueous humour, and the membrana hyaloidea, the disposition and structure of which, are very analogous to the serous membranes, and in which no lymphatic vessels have ever been detected, possess a faculty of absorbing, as active as the other membranes of the same kind.

When we apply a ligature upon one of the extremities, that part of the limb which is most distant from the heart swells, and the serosity accumulates in the cellular tissue. An analogous phenomenon sometimes occurs after extirpating cancerous mammæ, in which the operator is obliged to remove all the lymphatic glands from the axilla. This phenomenon has been explained, by supposing, that the ligatures, or the removal of the glands from the armpit, prevent the circulation of the lymph, and especially the absorption in the cellular tissue. Let us inquire how far this explanation is satisfactory. In the first place, the lymph is a very different fluid from the cellular serosity; again, may not the accumulation of this serosity depend upon other causes, than the obstructed action of the lymphatics, for example, the slow circulation of the venous blood? Besides, the removal of the glands from the axilla, do not always produce the effect which we have mentioned; and we frequently see scirrhus engorgements, and even a complete disorganization of the glands of the armpit, or groin, which are not accompanied with any œdema.

Numerous proofs are alleged of the absorption of the lymphatic vessels of the skin. It sometimes happens, when a person punctures his finger in dissecting a body in a state of putrefaction, that two or three days afterwards, the puncture becomes inflamed, and the corresponding glands of the armpit swell, and become painful. In some rare instances, these effects are accompanied by a vivid redness, and a small pain through the whole course of the lymphatic trunks of the arm. Under these circumstances, it is supposed, that the putrefied animal matter is absorbed by the lymphatics of the finger, that it is transported by them to the glands of the armpit, and that its passage has been marked by the irritation, and inflammation of the parts through which it has passed.

It cannot be denied that this explanation accounts, plausibly enough, for all the appearances, nor shall I pretend to assert that it is not correct; I suspect even, that its truth may hereafter be demonstrated. But when we reflect, that it is at this moment, one of the foundations of therapeutics, and that it often happens, that powerful remedies are employed on this principle, I think we do not go too far in doubting it. I shall make some reflections upon this explanation. In a great majority of instances, a puncture from a scalpel impregnated with putrid matter does not produce any injurious effects. It frequently occurs, that a puncture with a needle, perfectly clean, produces exactly the same phenomena as those which have been described; a slight blow, by which the end of the finger is contused, leads also to precisely the same effects. The simple impression of cold upon the feet, causes frequently a swelling of the glands of the groin, and a redness of the lymphatics, of the internal part of the leg and thigh. We may also add, that it is common to see the veins become inflamed, in consequence of punctures, and even to concur with the lymphatics. I saw a very striking, and unfortunate instance of this, in the body of Professor Lecler. This estimable philosopher died, in consequence of the absorption of putrid miasmata, from a slight scratch on one of the fingers of the right hand. The lymphatics and the glands of the armpit were inflamed, the glands were of a brown colour, and evidently diseased; but the internal membrane of the veins of the right arm exhibited unequivocal marks of inflammation, and the lymphatic glands of the whole body had undergone the same alteration as those of the right armpit.

There are also many facts in pathology, which are alleged as proofs of lymphatic absorption. After an impure coition, an ulcer appears upon the *glans penis;* in the course of a few days, one of the glands of the groin becomes inflamed, swollen and painful; or one of these glands inflames without any preceding ulceration upon the penis. This not unfrequently occurs during the first few days of a severe gonorrhœa. In these cases, it is supposed, that the orifices of the lymphatics absorb the venereal virus, and then transport it to the glands, in consequence of which, these parts are thrown into a state of engorgement. As they often return to a healthy state, after the application of mercurial frictions to the internal part of the thigh; it has been concluded, that the mercury is absorbed by the lymphatics of the skin, and that it passes through both them and the glands of the groin. These circumstances are sufficient to excite a suspicion of the absorption of the lymphatic vessels, but they certainly do not demonstrate it. This can never be absolutely demonstrated, until the substance, supposed to have been absorbed, is found in these vessels; and as no one has ever seen, in cases of venereal ulcer or gonorrhœa, pus, or when the mercurial unguent has been applied, mercury, in the lymphatic vessels or glands, it is evident, they cannot be considered as demonstrative evidence of lymphatic absorption. It is a different thing when we meet with pus, or mercurial ointment, or any other substance administered by frictions, in these vessels; we must then satisfy ourselves, whether they have penetrated by means of absorption. We shall see hereafter, with what facility those substances which are mixed with the blood often pass into the lymphatic system.

Mascagni cites an experiment made upon himself, which he thinks conclusive; I will literally translate it. "Having kept my feet plunged in water for several hours, I observed a somewhat painful swelling of the inguinal glands, and the transudation of a fluid through the gland. I was seized with a defluxion of the head, and had a constant discharge of a salt and acrid fluid from my nostrils. The following is the explanation which I give of these phenomena. When the lymphatics of the feet were filled with an unusual quantity of fluid, and the inguinal glands became swelled, the lymphatics of the penis were filled with more difficulty. The sanguineous vessels continuing to separate the same quantity of fluid, the lymphatic vessels were insufficient to remove the whole of it, as their action upon the fluid, which they naturally contain, was retarded; this is the reason why the rest of the secreted fluid transuded through the gland. Again; in consequence of the abundant absorption of the lymphatics of the feet, the thoracic duct was distended with great force, and the lymphatics of the pituitary membrane were incapable of absorbing freely, the fluids deposited upon their surface; hence the coryza." We learn, from this experiment, that Mascagni had the glands of the groin swelled, after having suffered his feet to remain some time in water; the explanation which follows is merely conjectural.

It is by inference alone, that absorption of the lymphatic vessels, in the deep seated organs, has been admitted; but it is not maintained by any experiments. The facts which are alleged in proof of it, such as metastasis, the resolution of tumours, the diminution of volume in the organs, &c. establish clearly enough the fact of internal absorption; but they by no means prove, that the lymphatic vessels execute it. I will mention a circumstance, which, in my opinion, is much more favourable to the doctrine of the absorption of the lymphatic vessels, than any which I have yet related. I am indebted to M. Dupuytren for this fact. A woman who had an immense tumour on the superior, and internal part of the thigh, with fluctuation, died in the Hotel-Dieu, in 1810. A few days before her death, an inflammation had taken place in the sub-cutaneous cellular tissue, on the internal part of the tumour. On the following day, M. Dupuytren examined the body. He had scarcely divided the skin that covered the tumour, before he remarked white points upon the lips of the incision. Surprised at this phenomenon, he carefully dissected the skin, to a certain extent, and found white lines, some of which were as large as crow quills, running over the sub-cutaneous cellular tissue. These were evidently lymphatic vessels, filled with puriform matter; the lymphatics were filled with the same fluid as far as the lumbar glands, but neither these glands, nor the thoracic duct, exhibited any trace of it.

It will be asked, if this fact is not enough to justify us in concluding, that the lymphatics had absorbed the fluid with which they were distended? This is probable, but in order to render it certain, it would be necessary to prove the identity of the fluid contained in the lymphatics, and that of the pus, with which the cellular tissue was filled. We only know this from appearance. M. Cruveilhier, who relates this fact, expresses himself thus: "I have said that this fluid was pus; it had the opacity, whitish colour, and consistence of pus." Now, the simple appearance is so deceitful, that we incur much risk in depending upon it. Under similar circumstances, two fluids, essentially different from each other, as milk and chyle, were for a long time confounded, merely because they had the same appearance; besides, we have no evidence that the lymphatics were not inflamed, and furnished the pus themselves, a thing which not unfrequently happens in the veins.

Under many similar circumstances, for example, after erysipelatous inflammation, with suppuration of the cellular tissue of the extremities, I have not been able to distinguish any marks of purulent matter in the lymphatic vessels. Besides, it is not uncommon to find, in cases of this kind, the veins which arise from the diseased part filled with a substance very analogous to pus.

In returning to the consideration of the absorbing power of the lymphatic vessels, we may remark, that it is not impossible that it may exist, but still this is far from being demonstrated; and as we are in possession of a great number of facts which appear, to us, to establish, positively, the absorption of the venous radicles, we shall consider the history of the different kinds of absorption, when we come to treat of the course of the venous blood.

We now return to the origin of the lymph, as admitted by physiologists.—If on the one side, the fluids which are supposed to be absorbed by the lymphatic vessels, differ from the lymph in their physical and chemical properties; and if on the other hand, the faculty of absorption in the lymphatic vessels be a phenomenon, the existence of which is very doubtful, what can we think of the received opinion of the origin of the lymph? Is it not evident that it has been lightly admitted, and that it has little probability in its favour? From whence then does the fluid arise, which we meet in these vessels? or, in other words, what is the most probable origin of the lymph? From the nature of the lymph, which has a great analogy to the blood; from the communication which anatomy demonstrates to exist between the termination of the arteries and the origin of the lymphatics; and from the facility and promptitude with which coloured and saline fluids are introduced into these vessels;* it appears to me very probable, that the lymph is a part of the blood, which, instead of returning to the heart by the veins, follows the route of the lymphatic vessels. This idea is not entirely new; it resembles very much, that of those anatomists who first discovered the lymphatic vessels, and who thought, that these vessels were destined to carry back a part of the serum of the blood to the heart.

This discussion of the origin of the lymph, may appear to some to be too elaborate; but it was indispensable to avoid the false opinions which have been entertained, of the absorption of this fluid. It is evident, that it is necessary to form a very different idea on this subject from what is found in works on physiology, and to limit ourselves to an investigation of the mode in which the lymph passes into the lymphatic extremities. But with what obscurity is this phenomenon surrounded? We are ignorant of its cause, mechanism, the disposition of the instruments which execute it, and even the circumstances under which it takes place. Indeed, as we have already remarked, it appears, that it is only under particular circumstances that the lymphatics contain lymph. There is nothing about this obscurity that should surprise us; we have already seen, and we shall have

* I have established this fact by direct experiments, an account of which I shall give below.

often occasion hereafter to remark, that it reigns over all the phenomena of life, to which we cannot apply the laws of physics, chemistry, or of mechanics; of consequence, over all those functions which relate to vital action and nutrition.

Course of the Lymph.

We have but a few words to say on this subject; authors have scarcely noticed it, though it is still vague, and our own observations on this point will be found far from satisfactory. This is an interesting subject of research, and one entirely new.

From the general arrangement of the lymphatic apparatus, its termination in the thoracic duct, and its cervical trunks, in the subclavian veins, and the form and arrangements of its valves, we cannot doubt, that the lymph passes from the different parts of the body, from which the lymphatics arise, towards the venous system. But the particular phenomena of its motion, its causes, variations, &c. have not yet been investigated.

The following remarks are the result of my own examination of this point. 1st. In man, and living animals, it is very rare that the lymphatics of the extremities, head and neck, contain lymph; their internal surface alone appears to be lubricated with a very thin fluid. In certain cases, however, the lymph is arrested in one or more of these vessels, distends them, and gives to them an appearance very analogous to that of varicose veins, differing only in colour. M. Sœmmering, has seen this often on the back of the foot of a female, and I have had occasion to observe a similar instance of it on the corona glandis. We find frequently, in dogs, cats, and other living animals, lymphatic vessels full of lymph, on the surface of the liver, gall, bladder, the vena cava of the trunk, the vena portæ, in the pelvis, and on the side of the vertebral column. The cervical trunks are also frequently filled with lymph, though it is by no means rare that they are found entirely empty. With respect to the thoracic duct, I have never seen it empty, even when the lymphatic vessels of the rest of the body were in a state of perfect vacuity.

2d. Why do those varieties exist in the presence of the lymph in the lymphatic vessels? why do those of the abdomen contain it more frequently than the rest? and why does the thoracic duct contain it constantly?—I acknowledge myself incapable of giving a satisfactory answer to either of these questions. The only circumstance which I think I have observed, but which I will not undertake positively to assert, is, that the lymph is found most frequently in the trunks of the lymphatics of the neck, when animals have been long deprived of every kind of aliment, and drink.

3d. As abstinence is prolonged in a dog, the lymph becomes more and more red. I have seen it when its colour was nearly that of blood, in dogs which had fasted eight days. It has appeared to me also, that, in these cases, its quantity is more considerable.

4th. The lymph appears to move slowly in the vessels. If we puncture it in man, during life; (I had once occasion to do this;) the lymph passes out but slowly and without a jet. M. Sœmmering had already made a similar experiment. When the lymphatic trunks of the neck are filled with lymph, we may easily insulate them to the extent of an inch. We may then perceive that the fluid which fills them, passes along very gently. If we compress them, so as to make the lymph, with which they are distended, pass into the subclavian vein, it is often half an hour before they become filled anew, or they remain empty.

5th. Nevertheless, the lymphatic vessels evidently possess a contractile power; they empty themselves, frequently, as soon as they are exposed to the air. It is probable that, in consequence of this contraction, they are almost always found empty, except the thoracic duct, in animals recently dead. This power is undoubtedly one of the causes which determine the introduction of the lymph into the venous system. The pressure which the lymphatics receive, from the contractility of the tissue of the skin, and other organs, muscular contraction, the pulsation of the arteries, &c. must have a considerable effect upon the course of the lymph. This is evident in the lymphatics of the abdominal cavity.

6th. We are completely ignorant of the use of the lymphatic glands; this is no doubt the reason why they have been the object of so much speculation. Malpighi, considered them as *small hearts,* which gave a progressive motion to the lymph; others have supposed that they served to form divisions in the lymphatic vessels, and to imbibe, like sponges, the superfluous humours, to give a nourishing juice to the nerves, to form fat, &c. In a word, almost every one has given, on this subject, an unbounded freedom to his imagination.*

We shall say no more on the course of the lymph; it may easily be seen, how much remains to be done, to throw light on this phenomenon, and, generally, upon all those which relate to the functions of the lymphatic system, and its utility in the animal economy. If our actual knowledge of this subject is so limited, with what confidence can we receive those medical hypotheses in which we hear of the thickening of the lymph, the obstruction and imperfect action of the lymphatic glands, and of the defective action of the absorbent mouths of the lymphatics, which are supposed to occasion dropsies? And how shall we determine to administer remedies, often violent, founded on such reasoning? The changes of structure and volume, which take place in the lymphatic glands, from age, must induce us to presume, that the action of the lymphatic system, undergoes modifications in the different periods of life; but there is nothing positively known on the subject.

COURSE OF THE BLOOD IN THE VEINS.

The object of the function which we are now about to examine, is to transport the venous blood from all parts of the body and lungs. Besides, the organs which execute it, are at the same time, the principal agents of absorption on the external, and internal parts of the body; with the exception of the absorption of the chyle, the lymph, and that which takes place from the mucous surfaces of the lungs.

Of the Venous Blood.

This name is given to that animal fluid which is contained in the veins, the right side of the heart, and the pulmonary artery; organs which, by their union, form the apparatus appropriated to the venous blood. This fluid is of a brownish red colour, so deep, that it has received the name of black blood. In some cases its colour is less deep, so as to be scarlet. Its odour is disagreeable

* I think it unnecessary to notice, particularly, the retrograde motion of the fluids in the lymphatic vessels; the observations of Darwin, and others, upon this subject, I conceive to be merely imaginary.

and *sui generis,* its taste is also peculiar; we perceive, however, that it contains salts, and principally the muriat of soda. Its specific gravity is something more than water; Haller found the medium to be, : : 1.0527 : 1.0000. Its capacity for caloric, may be expressed by 934, that of the arterial blood being 921, its medium temperature is 101° of Far. The venous blood, when taken from its vessels, and left to itself, forms, at the end of a few moments, a soft mass; by degrees this mass separates spontaneously into two parts, the one a yellowish transparent fluid, called the *serum;* the other soft, but nearly solid, of a deep brownish, red colour, which is called the *crassamentum;* the last occupies the lower part of the vessel the *serum* rising above it. Sometimes there is formed on the surface of the *serum* a thin, soft and reddish coat, to which the name of *crust of the blood*, has been very improperly given. This spontaneous separation of the elements of the blood, does not occur until it has remained, for some time, in a state of rest. If it be agitated, it remains fluid and retains, for a much longer time, its homogeneous appearance.

When venous blood is brought in contact with atmospheric air, or oxygen gas, it assumes a vermilion tint; with ammonia it becomes of a cherry red; with azote of a reddish brown, but much deeper colour.* While changing colour, it absorbs a considerable quantity of these different gasses. When kept for some time under a receiver, placed over mercury, it exhales a considerable quantity of carbonic acid. M. Vogel has very recently made some new researches on this subject.†

According to M. Berzelius, one thousand parts of the serum of the human blood contain,

	Water, - - - -		903.0
	Albumen, - - - -		80.0
Substances soluble in alcohol.	Lactate of soda and extractive matter, - -	4	
	Muriat of soda and potash	6	—10.0
Substances soluble in water.	Soda and animal matter, phosphat of soda, -	4	
	Loss, - - -	3	— 7.0
	Total,		1000.0

* For changes in colour, which the venous blood undergoes, when brought in contact with the different gases, see vol. iii. of the Chemistry of M. Thenard, p. 513.

† Annals of Chemistry, year 1816.

The serum sometimes presents a whitish milk-like appearance, from which it has been supposed, that it contains chyle; the substance that gives to it this appearance resembles oil.

The crassamentum of the blood is chiefly formed by the fibrine and colouring matter. When separated from the colouring matter, the fibrine is solid, whitish, insipid, and inodorous; it is heavier than water, does not produce any action upon vegetable colours, it is elastic when it is humid, and becomes brittle by dessication; by distillation, it furnishes a large quantity of the carbonate of ammonia, and a large mass of carbon, the ashes of which contain a considerable quantity of the phosphate of lime, a little of the phosphate of magnesia, carbonate of lime, and carbonate of soda. One hundred parts of fibrine are composed of,

Carbon,	53.360
Oxygen,	19.685
Hydrogen,	7.021
Azote,	19.934
Total,	100.000

The colouring matter is soluble in water, and the serum of the blood. When examined by a miscroscope, after being dissolved in these fluids, it appears, like most parts of the fluids in the animal economy, to consist of small globules; when dried, and calcined afterwards in contact with the air, it melts, bursts up into bubbles, burns with a flame, and forms a carbon, which cannot be reduced into ashes, but with extreme difficulty. This carbon, during its combustion, disengages ammoniacal gas, and furnishes a hundredth part of its weight of ashes. It is composed of,

Oxide of iron,	55.0
Phosphate of lime and a trace of the phosphate of magnesia,	8.0
Pure lime,	17.5
Carbonic acid,	19.5
Total,	100.0

It is important to remark, that there is not found in any part of the blood, either gelatin, or phosphate of iron, as was formerly believed. The respective proportion between the quantity of the serum and the crassamentum; those of the colouring matter and fibrine, have not been carefully examined, as we

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shall see by and by. It is probable that they are varied by an infinite number of circumstances.

The coagulation of the blood, has been, in turn, attributed to cold, the contact of air, and a state of rest; but John Hunter and Hewson demonstrated by experiment, that this phenomenon could not be referred to either of these causes. Hewson took fresh blood and froze it, by exposing it to a low temperature; the blood was afterwards melted, and it became fluid, and shortly coagulated as usual. John Hunter obtained a similar result. Thus it was proved, that coagulation of the blood is not produced by cold. It seems even that a temperature, somewhat high, is favourable to its coagulation. Experiment also proves, that the blood runs into a mass, when deprived of the contact of air, and agitated; in general however, repose, and the contact of air favour its coagulation.

But so far from referring the coagulation of the blood to any physical influence, it must undoubtedly be considered as essentially vital; that is, as giving demonstrative evidence, that the blood is endowed with life. We shall see, hereafter, of what importance the property of coagulating, possessed by the blood and other fluids, is in many of the phenomena of nutrition. To form a more precise idea of the coagulation of the venous blood, I placed, in the focus of a microscope, a drop of this fluid while it was still in a liquid state; it appeared like a red mass, but, as soon as it began to coagulate, the edges became transparent and granulated; the solid part, being almost opaque, formed an infinite number of fine meshes, or cells, which contained the fluid part; which was the most transparent. It was this disposition, which gave to the edge of the drop of blood, its granulated aspect. By degrees, these meshes became enlarged, by the retraction of the solid parts; in many places they entirely disappeared, and there only remained, between the external circumference of the drop of blood, and the edge of the central coagulum, an arborescent appearance, very analogous to what we have described, in speaking of the lymph; their divisions communicating with each other, like the vessels and nerves of leaves. This experiment must be made by a diffused or artificial light, for the direct light of the sun produces dessication, without coagulation. Under many circumstances, the blood coagulates, even when contained in the vessels; but in general, this phenomenon arises from disease. Some authors thought they had remarked, that the blood, in coagulating, became warmer, but John Hunter, and very recently Mr. J. Davy, have proved, that there is no elevation of temperature.

At the period when galvanism attracted so much attention in France, it was supposed, that if a portion of the coagulum, recently formed, was submitted to a galvanic current, that it contracted itself like the muscular fibres. I have often endeavoured to produce this effect, by submitting portions of coagulum, at the moment of their formation, to the action of the pile; but I have never seen any thing of the kind. I have varied these attempts in different ways, but have never been more fortunate. Very recently, I have repeated this experiment, with M. Biot, but the result was the same. The analysis of the venous blood, such as we have already pointed out, makes us acquainted with the peculiar elements of this fluid; but as all the substances absorbed in the intestinal canal, the serous membranes, and the cellular tissue, are mixed immediately with the venous blood, the result must be, that the composition of this fluid will vary, in proportion to the matter absorbed. There will be found, under different circumstances, alcohol, æther, camphor, and salts, which it does not contain generally, when these substances have been submitted to absorption, in any part of the body. The greater or less degree of promptitude, with which the blood runs into a mass, the solidity of the coagulum, the separation of the serum, the formation of an albuminous coat upon its surface, and the particular temperature of the fluid, in or out of the vessels, are phenomena which we shall examine in the article *arterial blood.*

Apparatus of the Venous Blood.

This is composed first of the veins; second of the right auricle, and ventricle of the heart; third, of the pulmonary artery.

Of the Veins.

The arrangement of the veins in the tissue of the organs, escapes our senses. When we first begin to distinguish them, they are presented under the form of an infinite number of small tubes, exceedingly delicate, communicating with each other in a sort of very fine net-work; they soon increase in volume, still preserving their reticulated arrangement. They in this manner form vessels, the capacity, form, and disposition of which, differ in each tissue, and even in each organ. Some organs appear almost entirely formed of venous radicles; such are the spleen, the cavernous parts of the vagina, the clitoris, the iris, the nipple, and the ureter, &c. When we force an injection into one of the veins, which pass out from these different tissues, they but rarely become entirely filled with the injected matter, which does not happen but rarely, when the injection is pushed into the arteries. The incision of these parts in man, or in living animals, causes blood to be thrown out, which has all the appearance of venous blood.

The venous extremities communicate with the arteries and lymphatic vessels; anatomy leaves no doubt on this point; but it appears that those extremities, the disposition of which is unknown, are also open on the different surfaces of the membranes, the cellular tissue, and even the parenchyma of the organs. M. Ribes, having forced mercury into one of the branches of the vena portæ, saw the villosities of the intestinal mucous membrane filled with this metal, which spread itself into the cavity of the intestine. In forcing air from the venous trunks, towards their origin, and overcoming the resistance of the valves, which is very easy in those bodies which are in a state of incipient putrefaction, the same anatomist has always found the air spread with great facility into the cellular membrane, although no sensible rupture of the venous walls had taken place. I have made similar remarks in forcing the air, or other fluids, into the veins of the heart. These facts, which have taken place since my experiments on venous absorption, of which I shall speak hereafter, agree perfectly with them.

The veins of the brain surround it on every side; they form a great part of the pia mater, and penetrate into the ventricles, where they contribute to form the plexus choroides. Those of the testicle, represent a very fine net-work, which covers the spermatic vessels, while those of the kidneys are short and voluminous. In leaving the organs to pass towards the heart, the veins affect a very different arrangement. In the brain they are lodged between the laminæ of the dura mater, protected by them, and are known by the name of sinuses. In the spermatic cord, they are flexuous, anastomosing frequently, and forming the pampini-form body. About the vagina, they are reticulated, in the uterus, they are very voluminous, with numerous flexuosities. In the extremities, head and neck, they are distinguished into deep seated, which accompany the arteries, and superficial, which are placed immediately under the skin, in the midst of the lymphatic trunks, which are found there. In proportion as the veins become distant from the organs, and approach the heart, they diminish in number, and increase in volume, so that all the veins of the body, which are innumerable, terminate in the right ventricle of the heart, by three trunks, the vena cava inferior, and superior, and the coronary vein.

I have said, that the small veins communicate with each other, by frequent anastomoses; this disposition exists also in the large veins, and in the trunks of the veins. The superficial trunks, in the extremities, communicate with the deep seated; the veins of the external part of the head, with those of the internal; the external with the internal jugulars; and the vena cava superior, with the inferior, &c. These anastomoses are advantageous to the course of the blood in these vessels. Many veins exhibit, in their cavities, folds of a parabolic form, called valves; they have two free surfaces, and two edges, the one of which adheres to the walls of the vein, while the other is left floating in it. The first is more distant from the heart, and the other much nearer to it. The number of the valves are not always the same; in general, they are the most numerous where the blood has to rise against its own gravity, and they have only a weak pressure to support them from the surrounding parts; they are wanting, on the contrary, in those parts where the veins are exposed to an habitual pressure, which favours the circulation of the blood, and in those which consist of canals, not extensible. They rarely exist in those veins which are less than a line in diameter. Sometimes the size of the valves is so great, as to fill completely the cavity of the vein; but at others, they are evidently too small to produce this effect. All anatomists have thought that this arrangement depended on primitive organization; but Bichat thought he had discovered that it arose from the state of contraction, or dilatation of the veins, when death took place.

I have endeavoured to satisfy myself of the correctness of Bichat's idea, but I acknowledge I have been unable to do it. I have not perceived that the distention of the veins had any influence upon the size of the valves; it has seemed to me, on the contrary, that they remain always the same; but that their form was altered by their contraction or dilatation, and it was probably this which deceived Bichat.

The veins are formed by three membranes, placed one over the other. The external is cellular, dense, and difficult to rupture. If we can depend on the works of anatomists, that which comes next is formed of parallel fibres, in the direction of the length of the vessel; and that this is easiest to be perceived, when the vein is large, and contracted. I have endeavoured, but without success, to distinguish the fibres of the middle membrane of the vein. I have always observed excessively numerous filaments interlaced in all directions, but which seemed to assume the appearance of longitudinal fibres, when the vein is folded longitudinally; a disposition which is always observed in the large veins. The sub-cutaneous veins of the extremities, the walls of which are very thick, will be found to afford the greatest facility, in examining the arrangement of this membrane. We are ignorant of the chemical nature of the fibrous coat of the veins; from some experiments which I have made, I suspect it is chiefly fibrine. It is extensible and firm, and does not present otherwise any peculiarity, in the living animal, in which it resembles muscular fibres. When irritated with the point of a scalpel, or submitted to a current of galvanic fluid, it does not exhibit any sensible contraction. The third membrane of the veins, or internal tunic, is extremely thin, and very much folded on that surface which is in contact with the blood; it is very flexible, and extensible, at the same time presenting a considerable resistance; it supports, for example, without being ruptured, the pressure of a ligature drawn strongly around it. Some of the veins, for example, the sinuses of the brain, the venous canals of the mouth, and the sub-hepatic veins have their walls alone formed by this membrane, being almost entirely destitute of the two others.

These three tunics together, form a very elastic tissue. In whatever direction the veins may be enlarged, they resume immediately their primitive form; nor can I imagine on what ground

Bichat has asserted that they are destitute of elasticity. Nothing can be easier than to satisfy ourselves that they possess this physical property to a very great extent. A large number of arteries and veins, called the *vasa vasorum*, and filaments of the great sympathetic, are sent to the veins; they are, therefore, far from being exempted from those diseases, to which the other parts of the animal body are subject. They sometimes seem to be affected by inflammation.

Of the right Cavities of the Heart.

The heart is so well known, that it seems hardly necessary to insist much upon its form and structure. I shall only allude to its principal characters. In man, the mamalia, and birds, it is formed into four cavities; two superior, which are called *auricles*, and two inferior, which are called *ventricles*. The left auricle and ventricle belong to the apparatus of the arterial blood; the auricle and ventricle of the right side, make a part of that of the venous blood.

It is not very easy to describe the form of the right auricle; its transverse diameter is the greatest; its cavity exhibits, at its posterior part, openings from the vena cava, superior and inferior, and coronary vein; internally it presents a depression, called the *foramen ovale*, which is open in the fœtus, but closed in the adult. At the bottom of the auricle is a large opening, which conducts into the right ventricle. The internal surface of the auricle presents a greater number of fleshy masses or columns, which are rounded or flattened, and which cross each other in various directions, exhibiting a sort of spongy tissue, spread over the internal surface of the auricle, and forming a coat of considerable thickness. At the place where the vena cava inferior is connected with the auricle, is a fold of the internal membrane, which is called the *eustachian valve*.

The right ventricle is a more spacious cavity, and has thicker walls than the auricle; it is of the form of a triangular pyramid, the base of which corresponds to the auricle and pulmonary artery, and its apex to that of the heart; all its surface is covered with long and rounded projections, which are called *columnæ carneæ*, their arrangement is very irregular; like those of the auricle, they form a reticulated or cavernous tissue, through the whole extent of the ventricle, particularly towards its apex. The columnæ carneæ of the ventricle, being generally larger than those of the auricle, form also a net-work, the meshes of which are coarser; some arising from the surface of the ventricle, terminate in forming one or more tendons, which are attached to the loose edge of the tricuspid valve, which is placed at the opening, by which the auricle and ventricle communicate with each other. At the side, and a little to the left of this, is the orifice of the pulmonary artery. The walls of the auricle and ventricle are formed of three tunics; the one exterior is of a serous nature, the internal is analogous to that of the internal membrane of the veins, and the middle is chiefly muscular and contractile; this coat is thin in the auricle, but of great thickness and strength in the ventricle. The innumerable fibres which compose it have a very intricate arrangement, many respectable authors have endeavoured, with great labour, to ascertain their direction; but, notwithstanding their patience and address, the disposition of these fibres is still but little known. Happily it is not necessary for us to form an exact idea on this point, to enable us to comprehend the action of the auricle and ventricle. The heart has arteries, veins, lymphatic vessels, and nerves, which arise from the great sympathetic, and are distributed to its walls and arteries, and perhaps even to its muscular tissue.

Of the Pulmonary Artery.

This artery arises from the right ventricle, and passes towards the lungs. At first, it forms but a single trunk, soon it becomes divided into two branches, one of which is sent to the right, and the other to the left lung; each of these branches are divided and subdivided, until they form an infinite number of small vessels, the tenuity of which is so great, that they are at last imperceptible by our senses. The divisions and subdivisions of each of these branches of the pulmonary artery, are remarkable in this, that they do not communicate with each other before becoming extremely small, the last divisions appear to be continuous, immediately, with the roots of the pulmonary veins. The pulmonary artery is formed of three tunics, the external is very strong, and of a cellular texture; the internal, is very smooth on its internal surface, and is always lubricated by a thin fluid. The middle tunic has circular fibres, which are very elastic, and were long thought to be muscular, though they evidently do not possess that character; its chemical nature appears to be nearly all fibrine, when tested by reagents.

Course of the Venous Blood.

According to the most distinguished physiologists, this is still but imperfectly understood. We shall only describe, at present, its most apparent phenomena, reserving more doubtful questions until we speak on the relations which exist between the course of the blood in the veins and arteries. We shall then speak of the cause which determines the entrance of the blood into the venous extremities. In order to form a general, but just idea, of the course of the blood in the veins, it is necessary to recollect, that the sum total of the cavities of the small veins, forms a much larger cavity, than those of the large, into which they pour their contents; and these again bear the same relation to the trunks in which they terminate. In consequence of this, the blood which goes from the extreme veins, passes always from a larger to a smaller cavity. The following hydrostatic principle, is therefore perfectly applied in this instance. When a fluid passes through a tube which is full, the quantity which traverses in a given time the different sections of the tube, must be always the same; but when the tube becomes larger, its velocity diminishes, and increases when the tube is smaller.

Experience confirms the exactness of this principle, and the justness of its application to the course of the venous blood. If we cut across a small vein, the blood passes out very slowly, but it escapes much more rapidly from a large vein. Many veins are destined to transport the blood contained in an organ towards the large trunks. In consequence of their frequent anastomoses, the compression, or even tying one or more of the veins does not prevent, nor even diminish the quantity of blood which is returned towards the heart; it only acquires a greater degree of velocity, in the veins which remain open. When a ligature is applied about the arm, preparatory to performing the operation of bleeding, the following phenomena take place. In the ordinary state, the blood which is carried to the forearm and hand, returns towards the heart by four deep-seated, and at least as many superficial veins. When the ligature is passed around the arm, the blood no longer passes by the sub-cutaneous veins, and traverses, with difficulty, those which are deep-seated. If one of the veins be then opened at the fold of the arm, a continued jet will be formed, which lasts as long as the ligature remains tight, and ceases when it is removed.

We often find the veins not much distended with blood; when, however, this fluid passes with the greatest rapidity, the reverse is the fact. In the extreme veins, it is very little the case. For a reason, easy to be understood, those circumstances which accelerate the motion of the blood in the veins, increase also the distention of the vessels. The introduction of the blood into the veins taking place in a continuous manner, every cause which operates as an obstacle to its course, produces a distention of the vein, and a greater or less degree of stagnation of the blood.

The walls of the vein appear to have a very feeble influence upon the course of the blood. They yield easily when its quantity is increased, and contract again when it is diminished. But this contraction is extremely limited, it is not sufficient to expel the blood entirely from it; this is constantly found to be the case in the recent subject. I have often seen the veins empty in the living animal, and at other times, I have observed that the column of fluid was far from filling up entirely the cavity of the vessel.

A great number of the veins, such as those of the mouth, the sinuses of the dura mater, testicle, and the liver, the walls of which form inflexible canals, can have no influence upon the motion of the blood, that passes through their cavities. We must attribute always, the faculty which the veins have of contracting, when the column of blood is diminished, to the elasticity of their walls and not to a contraction which has any analogy to that of the muscles. This contraction is much more remarkable in those which have thick walls, like the superficial veins. If the veins have, of themselves, but little influence upon the course of the blood, there are many auxiliary causes, the action of which is very manifest. All compression, whether continued or alternate, exerted upon a vein, can, when it is sufficiently strong to flatten the vein, obstruct the passage of the blood. If it be moderate, it opposes the dilatation of the vein from the pressure of the blood, and thus favours its motion.

The habitual pressure which the skin of the extremities exerts upon the veins, running beneath it, is one cause which renders the course of the blood in these vessels more rapid and easy. We cannot doubt this, as those circumstances which diminish the contractility of the tissue of the skin, are, sooner or later, followed by a considerable dilatation of the veins, and in some cases the production of varices. It is also known, that an appropriate bandage restores the veins to their ordinary dimensions, and the course of the blood to the internal parts. In the abdomen, the veins are submitted to the alternate pressure of the diaphragm and abdominal muscles; a cause which is favourable to the progress of the venous blood in this part. The veins of the brain support also a considerable pressure, which must produce the same result. Whenever the blood in the veins, passes in the direction of its weight, its progress is much easier than when it has to mount against it. We must not neglect to notice the relations of these auxiliary causes to the arrangement of the veins; where they are the most remarkable, the veins do not possess valves, and their walls are very thin, as we notice in the abdomen chest, cavity of the cranium, &c. But where they have less influence, the veins are furnished with valves, and the walls are thicker; lastly, where they are very weak, as in the sub-cutaneous veins, the valves are numerous, and the walls of considerable thickness.

If we wish to form a comparatively exact idea in this case, we have only to examine the internal saphæna, the crural, and the commencement of the external iliac veins, on a level with the opening of the femoral aponeurosis, destined for the passage of the saphæna vein; the contrast in the thickness of the walls will be found very striking. I have lately made this comparison, in the body of a criminal who was very muscular. The walls of the saphæna were as thick as those of the carotid artery; the crural, and especially the external iliac, had walls which were much thinner.

We must take care, however, lest we confound these circumstances, favourable to the course of the blood in the veins, with causes which act in a very different manner. For example, it is generally known that the contraction of the muscles of the fore arm and hand, during bleeding, accelerates the motion of the blood which escapes through the opening of the vein. Physiologists assert, that the muscles, in contracting themselves, compress the deep seated veins, and expel the blood, which passes then into the superficial veins. If this were the case, the acceleration would be only instantaneous, or at least of very short duration; while it is known to continue, in general, during the contraction. We shall see hereafter how this phenomenon may be explained. When the feet are plunged, for sometime, in warm water, the subcutaneous veins swell; this is generally attributed to the rarefaction of the blood. The true cause appears to me to be the increase in the quantity of the blood which is carried to the feet, and especially the skin; this augmentation would naturally accelerate the motion of the blood in the veins, inasmuch as in a given time they are traversed by a larger quantity of blood.

From the preceding remarks, we may easily understand, that the venous blood must be frequently stopped, or at least its course retarded, either from the too great pressure which the veins experience, in the different positions that the body assumes; or by different foreign bodies which are applied to it, &c. Hence the necessity of the numerous anastomoses, which we have said exist not only between the extreme veins, but those which are larger, and also in the large trunks. In consequence of these frequent communications, should one or more of the veins be compressed, so as not to allow the blood to pass, this fluid is turned aside, and arrives at the heart by other routes. One of the uses of the vena azygos appears to be, to establish an easy communication between the vena cava superior and inferior. I believe, however, its principal use is, to afford a common termination for the greater part of the intercostal veins.

There is nothing very obscure in the action of the valves of the veins; they are nothing else but true valves, which oppose the return of the blood towards the venous extremities, and which fulfil this office most perfectly, when they are large; that is, when they are favourably disposed for closing the cavity of the vein entirely. The friction of the blood against the walls of the veins, its adhesion to these walls, and its imperfect fluidity must modify the motion of the blood in the veins, and generally tend to retard it. But it is impossible, in the present state of physiology and hydrostatics, to assign, with precision, the *particular* effect of each of these causes.

What we have said of the course of the venous blood, is enough to show, that it is very much modified by an infinite number of circumstances. We shall have occasion to examine this more particularly hereafter, when we come to examine, generally, the circulation of the blood, and the difference in quality, between that of the arteries and veins. The venous blood from every part of the body, arrives at the right auricle of the heart by three trunks, which we have already mentioned, viz. two which are very voluminous, called the vena cava inferior and superior, and a small one called the coronary vein. It is very probable, that the blood passes through each of these veins with very different degrees of rapidity. It is evident that these three columns of fluid endeavour to penetrate into the auricle at the same time, and that this effort must be considerable.

Absorption exerted by the Veins.

Not only do the venous extremities receive blood directly from the extreme arteries, but they present another remarkable phenomenon. Every kind of gas or fluid, when put in contact with the different parts of the body, except the skin, passes immediately into the small veins, and arrives soon at the lungs with the venous blood. The same thing takes place with all those solid substances, susceptible of being dissolved by the blood or secreted fluids. In a very short time, they are introduced into the veins, and are transported to the heart and lungs. This introduction is called venous absorption. Let us study with attention this phenomenon, and take care that we do not suffer ourselves to be influenced by the term absorption. This seems to indicate, that the substances which pass into the veins are attracted by a peculiar force in these vessels. It is possible that such a force may exist, but it is evident that it is impossible, at present, to demonstrate it; it is also very possible, that this introduction is effected in some other mode. Without paying any attention, therefore, to the term *absorption*, it is only necessary to understand by this phenomenon, the passage of solid or fluid substances, when placed in contact with our organs into the extreme veins, the mode and mechanism of which are entirely unknown.

If we wish to form a distinct idea of this property, common to all the veins, we have only to introduce an aqueous solution of camphor into one of the serous or mucous cavities of the body, or to bury in the tissue of one of the organs, a morsel of solid camphor. Soon after, the air, which passes from the lungs of the animal, will possess, very distinctly, the odour of camphor. This experiment is easy to be made upon man, after the administration of an enema; it is seldom that, in the course of five or six minutes, the breath does not exhibit strongly the odour of this drug. Almost all the odoriferous substances which do not combine with the blood, produce similar effects. In the experiments which I made upon the absorption of the veins, I have found, that its rapidity varied according to the different tissues. It is, for example, much more rapid in the serous, than the mucous membranes; it is much more prompt in those tissues, which abound with sanguineous vessels, than those which contain few, &c. The corrosive quality of the fluids, or solids, submitted to absorption, does not prevent this being effected. It appears, on the contrary, to be much more prompt, than in those substances which do not attack the tissues.*

The intestinal villosities, formed partly by the venous extremities, absorb in the small intestine, all the fluids except the chyle. It is easy to satisfy ourselves of this, by introducing into the intestine those substances which are strongly odorous or sapid, and susceptible of being absorbed. As soon as the absorption begins, and as long as it continues, the properties of these substances may be recognised, in the blood taken from the branches of the vena porta, though we cannot distinguish them in the lymph, until a considerable time after the absorption has begun. We shall show in the sequel, that they do not arrive at the thoracic duct, through the medium of the lacteal vessels; but

* Much is said in modern works of physiology, of the peculiar sensibility of the mouths of the absorbent vessels; they are, say some, endowed with a delicate and sure tact, by which they discern those substances which are useful and suitable to them, and they refuse those substances which are injurious. These ingenious suppositions, which have a particular charm for minds eager after new ideas, are destroyed as soon as they are submitted to experiment.

through the communications of the arteries with the lymphatics. It is well known, that all the veins of the digestive organs, unite together in a single trunk, which is divided and subdivided in the tissue of the liver. This structure deserves to be noticed. In consequence of the great extent of the mucous membrane, with which the drinks and other fluids are in contact, and the rapidity of their absorption, by the mesenteric veins; a considerable quantity of fluid, foreign to the animal economy, may traverse the venous system of the abdomen, in a given time, and alter the composition of the blood. If the fluid, in this state, passed on to the lungs, and from thence to the rest of the organs, there would result the most serious consequences, as the following experiments will demonstrate.

I found that fifteen grains of bile forced suddenly into the crural vein, generally killed the animal in a few minutes. If a certain quantity of atmospheric air be introduced, rapidly, into the same vein, the same effects will follow; but an injection made in the same way, into one of the branches of the vena portæ, will not be found to produce any inconvenience. From whence arises the difference in these results? Does the passage of foreign fluids into the animal economy, through the innumerable small vessels of the liver, have the effect of mixing them more intimately with the blood, and as it were, diluting them with a large quantity of this fluid, so that their chemical nature becomes somewhat altered? This becomes the more probable, from the circumstance, that if the same quantity of bile or air be injected, very slowly, into the crural vein, it does not produce any sensible injury. It is, therefore, perhaps necessary, that the veins arising from the digestive organs, should pass through the liver, in order that they may mix more intimately with the blood, the substances absorbed in the intestinal canal. Whether this effect takes place or not, it cannot be doubted, that those agents which are absorbed from the stomach and intestines, do pass immediately through the liver, and that they cannot but have an influence upon this organ, which merits the attention of physicians.* We have said above, that the skin makes an

* It would be curious to inquire, why, of all the vessels of the liver, the branches of the vena portæ alone, by the disposition of their external membrane, called the

exception to the general law, that the veins absorb in every part of the body. This proposition merits a particular examination.

When the skin is deprived of the epidermis, and the sanguineous vessels which cover the external surface of the chorion are exposed, absorption takes place, as it does in every other part. After having applied a blister, if we cover the surface, which has been deprived of its epidermis, with a substance, the effects of which, upon the animal economy, we can easily observe; a few minutes are often sufficient for them to be manifested. Caustics applied to ulcerated surfaces, have often produced death. In order that the innoculation of the small pox, or the vaccine disease may succeed, it is necessary to take care to place the substance beneath the epidermis, and, of consequence, to place it in contact with the subjacent sanguineous vessels.

But it is very different when the skin remains covered with its epidermis. Unless the substances in contact with it are of a nature to change its chemical composition, or to excite an irritation in the corresponding sanguineous vessels, there is no sensible absorption. I know that this result is contrary to the received opinion on this subject. We think, for example, that when the body is plunged in a bath, that it absorbs the surrounding liquid; it is on this idea that the use of nourishing baths of milk and soup was founded. In a work recently published, M. Seguin has placed the point beyond doubt, that the skin does not absorb water when placed in it, by a series of very careful experiments. To satisfy himself if the same thing would take place with other fluids, this gentleman made the following experiments upon persons affected with syphilitic diseases.—He plunged their feet and legs in baths, composed of sixteen pounds of water, with one ounce of corrosive sublimate, dissolved in it; each bath lasted one or two hours, and was repeated twice daily. Thirteen patients were submitted to this treatment during twenty-eight hours, who did not present any evident marks of absorption; a fourteenth patient presented signs of this having taken place

capsula glissonii, are capable of contracting upon themselves, when the quantity of blood which runs through them diminishes. Perhaps this arrangement is most favourable to the course of the venous blood, which, to this portion of the vena portæ, passes from a narrow part into one that is large, while every where else it passes from a part that is large into one that is narrow.

after the third bath, but he had excoriations on both his legs; two others, who were in the same situation, exhibited the same phenomenon. In general, absorption does not take place, excepting in those persons where some portion of the epidermis is removed; however, at a temperature of 72° Faren. the corrosive sublimate is sometimes absorbed, but the water never.

Among the experiments of M. Seguin, there is one which appears to throw great light upon the absorbing faculty of the skin. After having weighed seventy-three grains of calomel, the same quantity, separately, of gamboge, scammony, *salt of Alembroth*, and tartar emetic, M. Seguin caused a patient to lie down on his back; and, having washed the skin of the abdomen nicely, he applied, carefully, upon the surface, these five substances; he then covered each of the places with a glass receiver, maintaining it in its situation with a linen bandage. The heat of the chamber was kept at about 68° Faren. M. Seguin remained with the patient the whole time, in order to prevent mistakes; the experiment lasted during ten hours and a quarter. The glasses were then removed, and the substances collected with great care, and weighed. The calomel was reduced to seventy-one grains and a third, the scammony weighed seventy-two grains and three quarters, the gamboge, a little more than seventy-one grains, the salt of alembroth was reduced to sixty-two grains; several pustules being developed on the spot where it was applied, the emetic tartar weighed sixty-seven grains. It is evident from this experiment, that those substances which were the most disposed to irritate the skin, and combine with the epidermis, were partly absorbed, while with the others this was not the case.

But that which does not take place from a simple application, may take place from frictions upon the skin with certain substances. We cannot doubt that mercury, alcohol, opium, camphor, vomits, purgatives, &c. penetrate by means of the venous system. It appears that these different agents pass through the epidermis, either through the pores, or are insinuated into the openings, by which the hairs or insensible transpiration pass out. Thus in considering the absorption of the skin, we perceive, that this membrane differs from the other surfaces of the body, only in being covered by the epidermis. While this coat remains perfect, and is not perforated by the substances placed in contact with the skin, no absorption takes place; but whenever this is the case, this action occurs in the skin, as in every other part.

I am not ignorant, that many persons will be surprised at my not hesitating to attribute to the veins the faculty of absorption, while the general opinion is, that all absorption is effected by the lymphatic vessels. But from the facts, already related under the article *absorption of the lymph*, and some others which I am now about to add, it is impossible for me at present to think otherwise. Besides, the opinion which I support is by no means new; Rhuysch, Boerhaave, Mechel, and Swammerdam professed it, and Haller supported it, though he was not ignorant of the anatomical labours of John Hunter. M. Delille and myself separated the thigh of a dog from the body, after having first stupified him with opium, for the purpose of avoiding the pain inseparable from a tedious experiment. We left the crural artery and vein alone untouched, preserving thus the communication between the thigh and trunk. These two vessels were dissected with very great care, that is, they were insulated to about the extent of two inches; their cellular coat was removed, lest it should conceal some lymphatic vessels. Two grains of a very subtle poison (*upas tieuté*) were then introduced into the foot. The effects of the poison were as prompt and severe, as if the thigh had not been separated from the body; so that the effects were manifested before the fourth minute, and the animal died before the tenth.

It may be objected, notwithstanding all the precautions which were taken, that the walls of the crural artery and vein still contained lymphatics, and that these vessels were sufficient to give passage to the poison. To do away this objection, I repeated upon another dog the preceding experiment, with this difference; I introduced into the crural artery the barrel of a small quill, upon which I fixed the vessel by two ligatures; the artery was divided in a circular direction between the two ligatures; I then did the same with the crural vein; thus all communication between the thigh and the rest of the body was interrupted, except the arterial blood, which passes to the thigh, and the venous which returned from it. The poison introduced into the foot produced its effects in the ordinary time, for example, about four minutes.

From this experiment, we cannot doubt, that the poison did pass from the foot to the trunk, through the crural vein. To render this phenomenon still more evident, we have only to press the vein between the fingers, at the moment when the poison is beginning to develop itself; these effects cease soon, but they return as soon as the vein is left free, and cease if we compress them anew. We may thus graduate them according to our pleasure. We may add to these facts, which appear to me to be decisive, the interesting experiments made by Flandrin. In the horse, the substances contained both in the large and small intestines, are generally mixed with a large quantity of liquid, which is more or less abundant, as we approach towards the rectum; it is absorbed, as it passes over this part of the intestinal canal. Now Flandrin ascertained, that the fluid contained in the lacteal vessels did not possess any odour analogous to that of this intestinal fluid: but on the other hand, that the venous blood of the small intestines had sensibly an herbaceous taste; that of the cœcum had a sharp and slightly urinous taste; that of the colon possessed the same character in a more remarkable degree. The blood in the other parts of the body presented nothing of the kind.

A half pound of assafœtida dissolved in an equal quantity of honey, was given to a horse; the animal was afterwards fed in the usual way, and killed in about sixteen hours. The odour of the assafœtida was very distinct in the veins of the stomach, small intestines, and cœcum; it was not remarkable in the arterial blood nor the lymph. Under the article *lymphatic vessels*, I have spoken of the experiments of John Hunter, to prove that these vessels are the only agents of absorption. The author endeavoured also to demonstrate, that the veins do *not* absorb; but these last are not more satisfactory or correct, than those which we have already mentioned. "I took," says Hunter, "a portion of the intestine of a sheep, after having divided the abdominal walls, I passed ligatures upon its two extremities, and then filled it with warm water. The blood which returned by the veins of this part did not appear more diluted or lighter than that of the other veins. I then tied the artery and all its communications, and examined the state of the vein. It was not swelled, the blood was not more diluted, and it did not give any indication of the presence of the water in its cavity. The veins, therefore, do not absorb."*

How many objections present themselves to this experiment, in the minds of those who think precision desirable in physiological inquiries! How could John Hunter know, from the simple appearance immediately after the experiment was performed, that the water was not absorbed, and not mixed with the blood of the vein? Again, how could this author, otherwise so eminent, have supposed that the action of the vein would continue when a ligature was passed around the artery? It would have been first necessary to determine the effect of tying an artery, upon the motion of the blood in the corresponding vein; a thing which had never been done. In another experiment, the same physiologist injected warm milk into a portion of the intestine; shortly afterwards he opened the mesenteric vein, and collected the blood as it passed out, and because he could not distinguish any trace of the milk, he concluded that no absorption of this fluid had taken place by the vein. But at the time of Hunter, they were far from possessing any means of detecting a small quantity of milk in a certain quantity of blood. At the present period, when animal chemistry is far more advanced, it is a difficulty not easily overcome.

These two experiments, when fairly considered, ought not to have any influence in deciding the doctrine of venous absorption. The other experiments, the number of which is six, are far from being conclusive, but on the contrary are still more defective. In a word, if it were necessary to adduce stronger evidence in favour of venous absorption, I would refer the reader to many parts of the body, in which the most expert anatomists have never been able to detect lymphatic vessels, or any other but blood vessels, such as the eye, the brain, the placenta, &c.; though absorption takes place with the same promptitude, as in every other part of the body. I will add, that all those animals which do not possess vertebræ, have blood-vessels, but not lymphatics, while absorption still manifestly takes place. Finally, the thoracic duct is much too small, to afford a passage to all the substances absorbed in the various parts of the body, and par-

* Medical Commentaries, chap. v.

ticularly the drinks.* All these phenomena are, at once, satisfactorily explained, when the absorption of the veins is admitted. Facts, experiments, and reason, then, concur in favour of the doctrine of venous absorption.†

Passage of the Venous Blood through the cavities of the right side of the Heart.

If the heart of a living animal be exposed, we can readily perceive, that the right auricle and ventricle contract and dilate alternately. These motions are so combined, that the contraction of the auricle takes place, at the moment, when the ventricle is dilated, and *vice versa;* the contraction of the ventricle occurs at the moment of the dilatation of the auricle. Neither of these cavities are capable of being dilated, without being at the same moment filled with blood; and when they contract, a part of it is necessarily expelled. But, such is the structure of the tricuspid and sigmoid valves, that the blood is compelled to pass, successively, from the auricle to the ventricle, and from this last to the pulmonary artery. We will now enter into a detail of this curious mechanism.

I have already observed that the blood contained in the three veins which terminate in the right auricle, make a strong effort to penetrate into this cavity. If it be contracted, this effort is unavailing; but when a dilatation takes place, the blood is precipitated into this cavity, fills it completely, and distends its walls slightly; it would penetrate into the ventricle, if this cavity were not, at the same moment, in a state of contraction. The blood then is limited, precisely, to filling at this moment the cavity of the auricle; but this soon contracts itself, and the blood, being compressed, must escape in that direction where the resistance is least. Now there are but two openings, the

* Some persons drink, as much as twelve pounds of mineral water, in the course of a few hours, and reject it through the kidneys in the same time.

† To recapitulate what we have said of the organs of absorption, in a general point of view, we may remark, first, that it is certain that the lacteal vessels absorb the chyle; second, that it is doubtful whether they absorb any thing else; third, that it has not been demonstrated that the lymphatic vessels possess the property of absorption, but it is proved that the veins are endowed with this power.

one towards the *venæ cavæ*, and the other in the direction of the ventricle. The sanguineous columns which arrive at the auricle oppose a certain resistance to its passage in the first direction; on the contrary, no obstacle exists to prevent its entrance into the ventricle, as, from its being dilated with force, it has a tendency to produce a vacuum, and thus to draw the blood from the auricle, instead of forcing it back. All the blood which passes from the auricle does not, however, enter the ventricle; experiment has shown, long since, that, at each contraction of the auricle, a certain quantity of this fluid flows back into the venæ cavæ. The undulation, produced by this cause, may be perceived, as far as the external iliac and jugular veins; its influence also, upon the course of the blood is very sensible in several of the organs, especially the brain.

The quantity of blood which flows back in this manner varies, according to the facility with which this fluid is allowed to penetrate into the ventricle. If at the moment of its dilatation, the ventricle contain still much blood which has not passed into the pulmonary artery, it can, of course, receive but a small portion from the auricle, and its reflux will, therefore, be much more considerable and extensive. This occurs, when the blood in the pulmonary artery is retarded by obstacles, placed in the substance of the lungs, or from the ventricle having lost its contractile power. The reflux, of which we are speaking, is the cause of the pulsation felt in the veins, in a certain disease, and which has received the name of *venous pulsation*. Nothing of the kind occurs in the coronary vein, as its mouth is supplied with a valve, which closes at the moment the auricle contracts.

The instant the contraction of the auricle ceases, the ventricle contracts, by which the blood contained in it, being pressed on every side, endeavours to escape; it would repass, very easily, into the auricle, did no obstacle exist, as may be inferred from what we have already said, this cavity being then in a state of dilatation. But this is prevented by the action of the tricuspid valve, which is placed at the opening between the auricle and ventricle, and will not allow the reflux of the blood, from the ventricle to the auricle. Pressed by the fluid with which the ventricle is distended, and which tends to pass into the auricle, this valve yields until it gets into a line perpendicular to the axis of the ventricle; then its three divisions perfectly close the opening, and its fleshy and tendinous columns will not allow it to go any further; this valve resists the effort of the blood, and prevents its passage into the auricle. But this is not the case with that portion of the blood, which, during the dilatation of the ventricle, is placed on that side of the valve which corresponds to the auricle; it is evident that, when the valve is raised, this portion of the blood will be thrown back into the auricle, and mixed with that received from the venæ cavæ, and coronary vein. Not being able to overcome the resistance of the tricuspid valve, the blood of the ventricle is compelled to enter into the pulmonary artery, into which it passes, after having pushed aside the sigmoid valves, which support the column of blood contained in this artery, at the moment when the ventricle is dilated.

We will now proceed to explain the phenomena, most apparent and best understood, exhibited by the venous blood in passing through the right cavities of the heart; there are also other circumstances, which I conceive to be worthy of particular attention. We should have but a very imperfect idea of this subject, if we supposed that, in each contraction of the ventricle and auricle of the heart, these cavities emptied themselves completely of the blood which they contained. In observing the heart of a living animal, we distinctly see, at the moment of contraction, the auricle or ventricle become sensibly diminished in volume; but it is evident, that at the instant the contraction ceases, much blood still remains in the auricle or ventricle. There is only a part of the blood of the auricle, which passes into the ventricle when it contracts. The same is true of the blood of the ventricle, a portion only of which passes into the pulmonary artery when the ventricle contracts; these two cavities, therefore, are always filled with blood. What is the precise portion of blood displaced, it may be inquired, and how much remains? They will vary, probably, according to the force with which the ventricle and auricle contract, the facility with which the blood traverses the pulmonary artery, the quantity of blood contained in the auricle or ventricle, and the efforts made by the three sanguineous columns which empty into the auricle.

When the blood has arrived at the heart, it is continually agitated, pressed and beaten by the motions of this organ; sometimes it flows back into the venæ cavæ, or precipitates itself into the auricle; again it passes with rapidity into the ventricle, is forced back suddenly into the auricle, and returns immediately afterwards into the ventricle; and again it penetrates into the pulmonary artery, and returns afterwards into the ventricle, undergoing at each displacement a violent agitation.* Agitated and pressed in this manner, with such prodigious force, the blood must undergo an intimate admixture of its constituent parts, during the time it remains in the cavities of the heart and pulmonary artery. The chyle and lymph which the subclavian vein receives, must be distributed equally in the blood of the two venæ cavæ. These two kinds of blood must also be compounded and completely united.

I am almost tempted to believe with Boerhaave, that the fleshy columns of the right cavities, independently of their uses in the contraction of these cavities, must have a considerable share in this agitation and admixture of the different elements of the blood. Indeed the blood which is found in the auricle and ventricle not only occupies these large central cavities, but also the small cells formed by these columns; of consequence at each contraction, it is forced partly into these cells, and is replaced at each dilatation, by a new portion of blood. Being divided thus into a great number of small masses, so as to occupy the cells, when it is again united and expelled; it cannot fail, from the excessive agitation it suffers, that the different elements of which it is composed, which have a great tendency to separate, should become thus intimately blended and combined. For the same reason, the chyle, lymph, and drinks, which are carried by the veins to the heart, and that have not become intimately mixed with the blood, must undergo this change in traversing the right cavities of the heart.

If we wish to form an idea of the influence of the right side of the heart, in this respect, we have only to force suddenly a quantity of air into the jugular vein of a dog, and examine the

* It is sufficient to touch but once the heart of a living animal, to form an idea of the energy of its contraction.

heart a few minutes afterwards, we shall see the air agitated and beaten about in the auricle and ventricle, forming a large mass of very fine froth. I have often observed these phenomena in living animals; and I have lately had an opportunity of confirming them upon a horse, the heart of the animal having been exposed, by an incision on the lateral part of the thorax, and a section of one of the ribs.

Passage of the Venous Blood through the Pulmonary Artery.

Notwithstanding the numerous efforts of physiologists, in investigating the motion of the blood in the arteries, much still remains to be done on this subject. Experience and observation are here our only faithful guides; our explanations must necessarily be imperfect, as hydrostatics, the only science which can furnish them, has scarcely been extended to the motions of fluids in flexible tubes.* I shall not adopt the descriptions of other authors, in giving an account of the motion and progress of the blood in the pulmonary artery. I prefer speaking of it at the moment, when the relaxation of the right ventricle takes place, and to see afterwards what happens, when the ventricle contracts, and forces the blood into the artery. This method appears to me to possess the advantage of placing this phenomenon in the most striking point of view; its importance does not seem, to me, to be sufficiently appreciated.

Let us suppose the artery full of blood, and left to itself; the fluid will be pressed by the walls of the vessel through its whole extent, which will have a tendency to approach each other, and efface completely its cavity; the blood, being thus compressed, will endeavour to escape on every side. Now there are but two

* I cannot resist quoting here, the appropriate remarks of D'Alembert on this subject "The mechanism of the human body, the velocity of the blood, and its action upon the vessels, cannot be reduced to a theory. We are ignorant of the precise action of the nerves, the elasticity of the vessels, their capacity, of the tenacity of the blood, and its different degrees of heat. Were even these things known, the great multitude of other cicumstances which would necessarily enter into such a theory, would probably conduct us to calculations altogether impracticable. It is one of those cases of a compound problem, one of the most simple parts of which it would be extremely difficult to resolve. When the operations of nature are too complicated," adds this illustrious philosopher, "to enable us to submit them to our calculations, experiment is the only method that remains for us."

directions in which this can take place; the one is the orifice next to the heart, the other the infinite number of delicate vessels in which the artery terminates in the tissue of the lung. The orifice of the pulmonary artery, towards the heart being very large, the blood would be easily precipitated into the ventricle, if there did not exist at this orifice, a particular apparatus destined to prevent it. I allude to the three sigmoid valves. At the instant when the contraction of the ventricle forces the current of blood into the artery, these valves are brought in contact with the walls of the artery, and perpendicular to its axis; but the moment that the blood has a tendency to flow back in the ventricle, it places them in such a situation, that they completely close up the cavity of this vessel. From the peculiar form of these valves, being that of a blind sac, the blood that enters into their cavity has a tendency to swell them out, and to give a circular form to their fibres. This valve is divided into three portions, each of which is semicircular; now if three semicircular bodies be brought together, there would necessarily exist a space between them. We might therefore suppose, that the valves of the pulmonary artery, when they are pressed back by the blood, would leave a space by which the blood would flow back into the ventricle. It is undoubtedly true, that if each valve was single, it would assume a semicircular form; but as there are three each acted upon by the blood at the same time that their sides are brought in contact with each other, and as they can each only be extended to a certain point, in consequence of the smallness of the space in which they are contained, they are therefore made to press each upon the other. The valves are, therefore, made to assume the form of a triangle, the apex of which is at the centre of the artery, and the sides in contact with each other, so as completely to intercept the cavity of the artery. Perhaps the small cartilaginous masses which exist at the apex of these triangles, may be intended to close, more accurately, the artery at its centre.*

If we wish to see the manner in which these three valves are brought in contact with each other, it may be done in the following manner; if we inject, gently, wax, or prepared tallow, into

* See Sennac's treatise on the structure of the heart.

the pulmonary artery, allowing it to pass from the ventricle, when the artery becomes filled, the valves will be forced into, and brought in contact with each other; so that the orifice of the vessel will be closed with sufficient exactness to prevent a single drop of the injection from returning back into the ventricle. When the wax or tallow has become solid by cooling, we may examine, at our leisure, the manner in which the opening of the artery is closed up by the valves. The blood not being able, therefore, to flow back into the ventricle, will pass into the ramifications of the pulmonary veins; into which the small branches of the pulmonary artery are continued; and this will continue to be the case, so long as the walls of the artery press, with sufficient force, upon the blood which they contain; an effect which, with the exception of the trunk and principal branches, continues until the whole of the blood is expelled. It may be supposed that the fineness of the small vessels, in which the pulmonary artery terminates, acts as an obstacle to the blood. This would be the case if their number were small, or if the sum of their diameters were less, or even equal to that of the trunk; but as they are innumerable, and as their aggregate capacity is much greater than that of the trunk, the current passes on with ease. It is, nevertheless, true, that a state of distention or weakness of the lung, renders this passage more or less easy, as will be more particularly shewn hereafter.

In order that the current of blood may pass with more facility, it is necessary that the power of contraction, in the different divisions of the artery, should be in proportion to their size. If, for example, the action of the small vessels were superior to that of the large, while the first would expel the blood which they contained, they would not be distended by the blood coming from the second, and the fluid would therefore flow but very slowly. Now experiment shews, that the contrary of this supposition is true. If the pulmonary artery of a living animal be tied, immediately beyond the heart, nearly all the blood contained in the artery, when the ligature was made, will pass promptly into the pulmonary veins, and arrive at the other side of the heart.

We have now observed what happens, when the blood contained in the pulmonary artery, is exposed to the action of this vessel alone; but, in the ordinary state, at each contraction of the right ventricle, a certain portion of the blood is propelled with force into the artery; the valves are instantly raised; the artery, through the whole extent of its divisions, is distended in proportion to the force with which the heart contracts, and the quantity of blood which is thrown into it. Immediately after its contraction, the ventricle becomes dilated, and at this instant, the walls of the artery react upon themselves; the sigmoid valves become depressed, and close the artery, until a new contraction of the ventricle raises them. Such is the second cause of the motion of the blood in the artery, which goes to the lungs; they are, as we have seen, alternate, let us endeavour to appreciate their effects. For this purpose, we will examine those phenomena which are most apparent in the course of the blood, through the pulmonary artery.

I have remarked, that at the moment when the ventricle forces the blood into the artery, its trunk, and ramifications, of a certain calibre, undergo an evident dilatation. This phenomenon is called the *pulsation* of the artery. This pulsation is very strong near the heart, but grows weaker as you pass from it, and seems to cease altogether, when the artery becomes very minutely subdivided. There is another phenomenon observed, when we open the artery, which is a consequence of the preceding. If the opening be near the heart, and in a place where the pulsations are very distinct, the blood passes out in a jet, with a jerk; if the opening is made at a distance from the heart, and in a small branch of the artery, the jet is continuous and uniform; lastly, if we open one of the very small vessels in which the artery terminates, the blood no longer passes out in a jet, but spreads itself in a uniform sheet. We see, in the first place, in these phenomena, a new application of the principle of hydrostatics quoted above, relative to the influence which the size of the tube has upon the fluid, which runs through it; the larger the tube, the less the velocity of the fluid passing through it. As the aggregate capacity of the ramifications of the artery increases as they approach towards the lungs, the velocity of the blood is necessarily diminished.

With respect to the pulsation of the artery, and the jerk of the blood, as it escapes from an opening in it, we see, evidently, that these two effects are the results of the contraction of the right ventricle, and the introduction of a certain quantity of blood into the artery, which is thus effected. Why are these two effects weakened at a distance from the heart, and why do they cease altogether, in the last divisions of the artery? It is not impossible, I think, to give a satisfactory mechanical reason for this. Suppose a cylindrical canal, of a given length, with elastic walls, and filled with a fluid; if a new quantity of fluid be suddenly introduced into it, the pressure will be felt equally upon every point of the walls, which will be equally distended. Suppose, now, that this canal is divided into two parts, the sections of which, together, form a surface equal to that of a section of the main trunk of the canal; the distention produced by the sudden introduction of a certain quantity of fluid, will be less perceptible in the two divisions, than in the trunk; because, the total circumference of the two canals, being greater than that of the one canal alone, its resistance will be greater. If we suppose that these two last are divided, and subdivided, indefinitely, as the sum of the circumferences of the small tubes, will be greatly superior to that of the great trunk; the same cause which will produce a sensible distension in the canal, and its principal divisions, will not be appreciable in the smallest subdivisions, in consequence of the greater resistance of their walls.* This phenomenon will be still more remarkable, if the capacity of these divisions, instead of being equal, is greatly superior to that of the trunk.

This last supposition is realised in the pulmonary artery; the capacity of which increases, as it becomes divided and subdivided. It is evident, therefore, that the effects of the introduction of a quantity of blood into this artery, at each contraction of the right ventricle, must diminish as it is propagated, and at last cease altogether, in the last divisions of the vessel. It must not be forgotten, that the contraction of the right ventricle, is the

* In order to understand this, it is necessary to recollect, that the surfaces of circles are proportional to the squares of their circumferences. Thus, in the division of the canal into two branches, as we have supposed, if each circumference was only the half of the principal canal, the surfaces of each of the secondary canals, would be but the fourth part of the surface of the primitive canal, and these two surfaces united, would form but the half of this canal; in order that they should be equal, therefore, it is necessary that the circumferences of the two divisions, taken together, should exceed the circumference of the canal.

cause which keeps constantly in play, the elasticity of the walls of the artery; that is, which distends them so as to overcome the constant tendency which they have to approach towards each other, and expel the blood. From this, it will be perceived, that there is in fact, but one cause which gives motion to the blood, in the pulmonary artery; this is, the contraction of the ventricle, that of the artery being but the effect of the distention that it undergoes, at the instant when a certain quantity of blood penetrates into its cavity, being forced there by the ventricle.

Authors have thought, that they perceived in the contractions of the pulmonary artery, something analogous to that of the muscles. But when irritated with the point of an instrument, or caustics, or when submitted to the influence of a galvanic stream, no motion, analogous to muscular contraction, has ever been observed. We must therefore, consider this contraction as an effect of the elasticity of the walls of the vessel. In order to estimate the importance of the elasticity of the walls of the artery, let us suppose for an instant, that with its dimensions and ordinary form, it became an inflexible canal, immediately the course of the blood would be completely changed. Instead of traversing the lungs in a continued stream, it would only enter the pulmonary veins at the moment that it was propelled forward by the ventricle; at the same time it will be necessary to suppose that the artery would be always perfectly filled with blood; for if it were otherwise, it would be required that the ventricle should contract itself frequently before the blood would be made to pass into the lungs. Instead of this, observe what really takes place; the ventricle ceases for some moments to send blood into the artery; the course of the blood in the lungs, nevertheless continues, as the artery contracts in proportion as it is emptied, and it requires, that the time of emptying itself completely should be passed over, before the course of the blood into the lungs is completely stopped; now this suspension can never take place during life. The passage of the blood through the lungs is necessarily continued, and nearly equally rapid, whatever may be the quantity of blood thrown into the pulmonary artery at each contraction of the ventricle.

Various attempts have been made to determine the quantity of blood thrown into the pulmonary artery, at each contraction of the ventricle. In general, the estimate of its capacity has been formed on the supposition, that all the blood it contains at the moment of its contraction, passes into the artery; the estimate has been considerable. From what has been said above, however, it will be perceived, how inaccurate this calculation must be, inasmuch, as only a part of the blood contained in the ventricle is thrown into the artery; and, as it is impossible to know how much is thrown out, and how much remains, it is evident that all these calculations give but an imperfect idea of the truth. Besides, it is much more important to know the mechanism, by which the blood passes from the ventricle into the artery, and its course in this vessel; the quantity of blood which passes in a given time, even if it were known, would not be a circumstance of much importance.

ON RESPIRATION,

OR

THE TRANSFORMATION OF VENOUS INTO ARTERIAL BLOOD.

The blood, in passing from the small vessels in which the pulmonary artery terminates, and entering into the ramifications of the pulmonary veins, becomes changed in its nature, in consequence of the contact of the air, and acquires the peculiar qualities of the arterial blood. It is this change in the properties of the blood, which essentially constitutes the function of respiration. Some authors attach a different idea to respiration; it is often defined, the introduction and discharge of air from the lungs, but this double motion may take place without the function of respiration being performed. Others have thought that it consisted in the passage of the blood through the lungs; but it often occurs that this is effected without respiration. To study, successfully, this function, we must have an exact knowledge of the structure of the lungs, and precise notions of the chemical and physical properties of the atmospheric air; we must also understand by what mechanism the air is made to penetrate into, and pass out from the chest. When we have described each of these points, we shall then consider the phenomenon of the transformation of venous into arterial blood.

Of the Lungs.

The lungs are two spongy, and vascular organs of considerable volume, situated on each side of the chest, their parenchyma is divided and subdivided into lobes and cells, the number, form and dimensions of which, are difficult to determine. From an attentive examination of a pulmonary cell, we learn that it is formed of a spongy tissue, the spaces of which are so small that it requires a glass of strong magnifying powers to see them distinctly; these spaces communicate with each other, and are enveloped by a delicate cellular tissue, which separates them from the neighbouring cells. A portion of the bronchiæ and pulmonary artery terminate about each of the cells. The artery is distributed about the tissue of the cells, but in a manner which is not known, it appears to terminate in an infinite number of minute ramifications, in the pulmonary vein. I am myself disposed to believe, that these numerous small vessels, in which the pulmonary artery terminates, and the vein commences, by crossing and anastomosing with each other in different ways, form the spaces of the cells.* The small divisions of the bronchiæ, which end about the cells, do not penetrate into their interior, but finish suddenly when they arrive at the parenchyma.

This last circumstance appears to me remarkable, for inasmuch as the bronchiæ do not penetrate into the spongy tissue of the lungs, it is improbable, that the surface of the cells with which the air is in contact, is covered by the mucous membrane. Minute anatomy, at least, cannot demonstrate its existence in this place.

A part of the eighth pair of nerves, and some filaments of the sympathetic, are distributed to the lungs; but we do not know precisely how they are arranged. The external surface of the organ is covered by the pleura, a serous membrane analogous to the peritoneum, both in structure and functions. About the bronchiæ, and near the place where they enter into the tissue of the lungs, there are a certain number of lymphatic glands, the colour of

* This arrangement exists, more evidently, in the lungs of reptiles.

which is nearly black, and about which a small number of lymphatic vessels, which arise deep in the pulmonary tissue, terminate.

The art of fine injections furnishes us with some information relative to the lungs, which must not be omitted If we force an injection of mercury, or simply of coloured water, into the pulmonary artery, the substance injected, will pass into the pulmonary veins, and, at the same time, a part will penetrate into the bronchiæ, and pass out by the trachea. If the injection be made into the pulmonary veins, it passes into the pulmonary artery, and in part into the bronchiæ. Again, if the injection be introduced through the trachea, we shall find that it penetrates into both the pulmonary artery and veins, and even into the bronchial artery. The lungs fill a great part of the cavity of the chest, enlarging and contracting with it; and, as they communicate with the atmosphere by the trachea and larynx, every time that the chest is enlarged, they are distended by the air; which is again expelled when the chest returns to its former dimensions. It is necessary therefore, to stop a moment to examine this cavity. The chest or thorax is of a conical form, the apex of which is above, and the base below; posteriorly, it is formed by the dorsal vertebræ, anteriorly by the sternum, and laterally by the ribs; these last are twelve on each side; and are distinguished into true and false. There are seven of the first, and five of the last. The true ribs are above; they are articulated posteriorly, with the vertebræ, anteriorly they are articulated with the sternum, by means of a prolongation, called the cartilages of the ribs. It is the length, disposition, and motion of the ribs upon the vertebræ, which determine the form, and dimensions of the chest.

The same muscle which, as we have already seen, constitutes the superior wall of the abdomen, forms also the inferior wall of the thorax. It is attached, at its circumference, to the lower part of the chest; but its centre is elevated towards this cavity, and forms, when it is in a state of relaxation, an arch, the middle part of which is on a level with the inferior extremity of the sternum. Thus the cavity of the thorax is divided into two portions, a superior or thoracic, and an inferior, or abdominal portion. In the first, indeed, the thoracic organs, such as the heart, lungs, &c. only are lodged. The second contains the liver, spleen and stomach. Numerous muscles are attached to the bones which form the outline of the thorax; of these muscles, some are intended to render the ribs less oblique upon the vertebral column, or to enlarge the capacity of the chest; others depress the ribs, render them more oblique upon the vertebræ, and diminish thus the capacity of the chest.

It will be proper for us to investigate the mechanism, by which the chest enlarges or contracts itself; many of the phenomena of respiration being immediately connected with these variations of capacity. The chest may be dilated vertically, transversely, and from before backwards; that is to say, in the directions of its principal diameters. The principal, or, to speak more correctly, the only agent of its vertical dilatation is the diaphragm, which, in contracting itself, has a tendency to lose its arched form, and to become a plane; a motion which cannot be effected without the thoracic portion of the chest being increased, and the abdominal diminished. The sides of this muscle being fleshy, and corresponding to the lungs, descends more than the centre, which, being tendinous, is incapable of making any effort of itself, and is also retained by its attachment to the sternum, and its union with the pericardium. In most cases, this depression of the diaphragm is sufficient for the dilatation of the chest; but it sometimes happens, that the sternum and ribs, by changing the relation between them and the vertebral column, produce a sensible augmentation of the cavity of the thorax.

Nothing is easier to conceive, than the mechanism of this motion, when the physical arrangements of the part are well understood. It has, however, been a subject which has been discussed with great animation by some distinguished authors, who have, perhaps, given an importance to this question, which it does not merit. If such controversies led to truth, we should not regret the time which the learned have devoted to them; but it is rare that this is the result, at least it has not happened, as respects the mechanism of the dilatation of the thorax. After a great number of discussions and experiments, apparently accurate, Haller's opinions, which appear to me far from satisfactory, have prevailed. I will explain myself upon this point, with all the deference which so high an authority demands.

His explanation of the dilatation of the thorax, now generally admitted, reposes upon bases which I cannot admit. He assumes, that the first rib is nearly immoveable,* and that the thorax is incapable of any motion, as a whole, either above or below.† It is difficult to imagine, how so acute an observer as Haller, should have advanced, and supported such an idea; for we have only to examine upon ourselves the motions of respiration, in order to see that the sternum and first rib are elevated during inspiration, and depressed in expiration. The examination of the recent subject, affords the same result; we have only to press the sternum superiorly, and it will be found, with all the sternal ribs, to yield; the first moves upon the vertebral column, and the thorax is considerably enlarged.

After having assumed, that the first rib is nearly immoveable, Haller asserts, that the second possesses five or six times more motion than the first; that the third is greater than the second; and that their mobility increases as you approach towards the lower ribs. With respect to the true ribs, the only ones which we are at present considering, I believe the fact to be directly the reverse of that advanced by Haller; that is, that the first rib is more moveable than the second, this again than the third, and so on until you arrive at the seventh. But to judge accurately of the degree of mobility of the ribs, we must not confine ourselves to observing at their extremities the motions they execute. For, as they are of unequal lengths, a slight motion in the articulation, when the rib is long, will appear very great in its extremity; in the same way, an extensive motion in the articulation of a short rib, would appear trifling, if examined at its extremity. It is necessary, therefore, in considering the motion of the ribs, to suppose them all of an equal length; if this be done, it will then be evident, that their mobility diminishes from the first, towards the seventh, the last being nearly immoveable.

* Primum par (costarum) firmissimum est, inde ut quæque inferiori loco ponitur, ita facilius emovetur, donec infirma mobilissima fluctuet. Haller, Elementa Physiologiæ, tom. iii. p. 59, lib. viii.

† Totum tamen pectus, ut nunquam elevari vidi, ita nunquam deprimi.

HALLER, *loc. cit.*

The anatomical arrangement of the posterior articulations, occasions this difference of mobility. The first rib has but one articulating facette at its head, and is only attached to one vertebra; it has no internal ligament, nor any costo-transverse ligament. The posterior ligament of the joint, with the transverse apophysis, is horizontal, and cannot obstruct either the elevation or depression of the rib.

None of these circumstances, which are so favorable to motion, are found to exist about the other ribs; they have each two articulating facettes at their head, and are articulated with two vertebræ. They have an internal ligament in the articulation; which prevents a gliding motion; a costo-transverse ligament attached to the superior transverse apophysis, which prevents the rib from descending; a posterior ligament, directed from below, upwards, is seen behind the articulation of the tuberosity, and prevents the rib from rising. Different shades in the disposition of these different ligaments, permit the various degrees of mobility, of which we have spoken. Besides, it is evident, that a less degree of mobility existing in the long ribs, this is made up by the circumstance of their length, by which they are enabled to execute as extensive motions as the first, although they are less moveable; for the same reason, it is quite possible that they may exhibit even a greater extent of motion This compensation is indispensable, as the true ribs, their cartilages, and the sternum can only move together, and the motion of one of these pieces must therefore, follow that of all the rest. It would follow then, that if the inferior ribs were the most moveable, they would be incapable of executing a greater extent of motion, than that of the superior; and the solidity of the thorax would be diminished, without any advantage to its mobility.

In most subjects, and frequently even in advanced age, the sternum is composed of two pieces, articulated by a moveable symphisis, on a level with the cartilage of the second rib. This arrangement, by permitting the superior extremity of the inferior piece to project a little forwards, assists in enlarging the chest, in a manner which I think has never been remarked.

But what are the muscles that elevate the sternum and ribs, and, of consequence, dilate the chest? According to Haller, the intercostal muscles are the principal agents of this elevation. The first intercostals, he remarks, find a fixed point in the first rib, which is immoveable, and elevate the second; and all the intercostal muscles, successively, taking the superior rib as their fixed point, elevate the inferior. But we have just seen that the first rib is far from being immoveable; the explanation of Haller, therefore, necessarily, falls to the ground; nor can I believe that the internal and external intercostals, whatever may have been said to the contrary, could produce the elevation of the ribs. The muscles which appear to me to be destined to this purpose are those which, having one extremity mediately or immediately attached to the vertebral column, the head, or superior extremities, can act, directly or indirectly, upon the thorax, so as to elevate it. Among these muscles, I will cite the anterior and posterior scaleni muscles, the muscles of the neck, which are attached to the sternum, &c. I will also add another muscle, to which no one has ever attributed this use; I allude to the diaphragm. This muscle indeed, is attached at its circumference, to the inferior extremity of the sternum, the seventh true, and all the false ribs; when it contracts, it forces down the abdominal viscera, but, in order to do this, the sternum and ribs must present a resistance sufficient to counteract the effort made in the opposite direction. Now, this resistance can be but imperfect, inasmuch as all these parts are moveable; for this reason, every time that the diaphragm contracts, it must elevate the thorax, more or less. In general, the extent of the elevation, will be in direct proportion to the resistance of the abdominal viscera, and the mobility of the ribs.

In the general elevation of the thorax, the form of this cavity, and the relations of the bones which compose it, are necessarily altered. The cartilages of the ribs appear to be peculiarly adapted to this purpose. As soon as they become ossified, and of consequence lose their elasticity, the chest becomes immoveable. At the same time, that the sternum is carried superiorly, its inferior extremity is directed a little anteriorly; it experiences thus a slight oscillatory motion; the ribs become less oblique to the vertebral column; and they separate a little, the one from the other, the inferior edge being directed outwards, in consequence of a slight inflexion which the cartilage undergoes. All these phenomena can only be distinctly observed in the superior ribs, they are scarcely perceptible in the inferior.

There results from this elevation of the thorax, a general enlargement of this cavity, both from before, backwards, laterally, and from above downwards. This enlargement is called inspiration; it exhibits three well marked degrees. First, *ordinary inspiration,* which is made by the depression of the diaphragm, and an almost insensible elevation of the thorax. Second, *a deep inspiration,* in which the elevation of the thorax is evident, at the same time that the diaphragm is depressed. Third, *forced inspiration,* in which the dimensions of the thorax are augmented in every direction, that the physical disposition of this cavity will permit. To the dilatation of the thorax, succeeds expiration; that is, the return of the thorax to its ordinary position and dimensions. The mechanism of this motion is precisely the reverse of that which we just described. It is produced by the elasticity of the cartilages and ligaments of the ribs, which tend to react upon themselves, when the relaxation of those muscles which elevated the thorax permit it, and finally by the contraction of a great number of muscles so disposed, that they depress the thorax and draw it back. Among these muscles, which are very numerous and very strong, it is proper to mention the large muscles of the abdomen, the great dorsal, the sacro-lumbalis, and the serratus posticus inferior, &c.

The contraction of the thorax, or expiration, presents also three degrees; first, ordinary expiration, second, deep expiration, third, forced expiration. In ordinary expiration, the diaphragm, being relaxed, is crowded up by the abdominal viscera, which are pressed by the anterior muscles of this cavity, and cause a diminution of the vertical diameter of the thorax. The relaxation of the inspiratory, and a slight contraction of the expiratory muscles, permit the ribs and sternum to resume their ordinary relation to the vertebral column, and thus produce a strong expiration. But the retraction of the chest may go still further than this. If the abdominal and other expiratory muscles contract, forcibly, there will result from this a more remarkable crowding up of the diaphragm, a much greater depression of the ribs, and a much stronger contraction of the base of the chest, and, of consequence, a considerable diminution of the capacity of the thorax. This is called forcible expiration.

Of the Air.

The earth is surrounded on every side by a very thin and transparent fluid, called the air; the whole mass of which is called the atmosphere. It extends from the surface of the earth to a height of about fifteen or sixteen leagues. The air is an elastic fluid; that is, it possesses, in itself, the property of exercising a pressure upon those bodies which it surrounds, and upon the walls of those vessels which contain it. This property supposes in the particles of which the air is composed, a constant tendency to repel each other. Another property of the air is *compressibility;* that is, its volume may be diminished, in proportion to the pressure to which it is submitted. Experiment informs us, that the same mass of air, when subjected successively to different degrees of pressure, occupies spaces or volumes which are in an inverse ratio to the degrees of pressure; so that the pressure becoming double, triple, or quadruple, the volume is reduced one half, one third, or one fourth.

In the atmosphere, the pressure that any given mass of air supports, is in proportion to the weight of those strata which are above it; its weight and density therefore, diminish as we rise from the earth. At the surface of the earth, the pressure of the atmosphere is the result of its total weight. This pressure is capable of sustaining a column of mercury thirty-two inches high; the instrument employed for this purpose, is called a barometer. Different physical circumstances cause a slight variation in the atmospheric pressure. It is, for example, weaker at the summit of mountains than in vallies; it is greater when the air is charged with humidity, than when it is dry. These variations may be very accurately appreciated by means of a barometer.

Like all other bodies, the air is dilated by heat; its volume augments 1.266 for every degree of heat of the centrigrade thermometer. The air is heavy; this we may satisfy ourselves of, by weighing at first, a balloon filled with air, and weighing it afterwards, when it has been emptied by means of an air-pump. It has been found in this way, the temperature being at 0 and when the barometer was raised to thirty inches, that sixteen cubic inches of air weighs 19 grains; the same volume of water weighed 2 pounds, 3 oz. 5 dr. Water is therefore 770 times heavier than air.

The atmosphere is more or less charged with humidity; this arises from the continual evaporation of those waters which cover the surface of the earth. We find from experiment, that water is changed into vapour at all temperatures, but this takes place most rapidly, when the temperature is highest. Further, the air can only contain a certain quantity of vapour at a given temperature; when it is saturated the humidity is extreme. The nearer it approaches this state the greater is the humidity; the instruments which indicate the humidity of the air, are called hygrometers. When, in consequence of cooling, or any other cause, the air is incapable of containing all the vapour which it before possessed, this excess assumes the form of mist, or clouds, or is precipitated in the form of rain, or snow, &c. The vapour of water being lighter than air, and causing it to become dilated when it is mixed with it, the result is, that humid is much lighter than dry air.

Notwithstanding its thinness and transparency, the air refracts, intercepts, and reflects light. In a small mass, we see too few rays to have its colour produce a sensible impression upon our eyes; in a large mass the colour is very distinctly blue. The interposition of large masses of air, gives also a blueish tint to distant objects. The air is of great importance in chemical phenomena. It was regarded for a long time, as an element; its composition was first suspected by John Ray, in the seventeenth century, and was afterwards fully established by Lavoisier. The air is composed of two gasses, possessing very different properties. First. *Oxygen* is a little heavier than atmospheric air, and combines with all simple bodies; it is one of the elementary principles of water, and vegetable and animal substances; and of the greater parts of known bodies, it is necessary to combustion and respiration. Second. *Azote* is rather lighter than air, is one of the elements of ammonia, and of animal substances, and extinguishes bodies in a state of combustion.

The proportions of oxygen and azote, which enter into the composition of air, are determined by means of instruments called eudiometers. In these instruments we produce the combination of oxygen with some combustible body, such as hydrogen or phosphorus, and the result of this combination makes us acquainted with the quantity of oxygen, that the air contained. It is thus found, that a hundred parts of air in weight, contained 21 parts of oxygen and 78 of azote. The proportions are the same, in all places, and at all heights, and have not undergone any sensible change in the fifteen years, which have elapsed, since chemistry has established this point in a positive manner. The air contains, besides oxygen, azote, and the vapour of water in a variable quantity, as we have already remarked, a very small quantity of carbonic acid; the proportion of which is not fixed in a very rigorous manner. Nearly all combustible bodies decompose the air, at a temperature peculiar to each. In this decomposition, they combine with the oxygen, and leave the azote free.

Inspiration and Expiration.

If we recollect the disposition of the pulmonary cells, the extensibility of their tissue, their communication with the external air, by means of the bronchiæ, the trachea, and the larynx, we shall be easily able to conceive that, every time the chest is dilated, the air rushes into the lungs, in a quantity proportioned to the degree of dilatation. When the chest contracts itself, a part of the air contained in it is expelled, and rushes out through the glottis. In order that the air may arrive at the glottis in inspiration, or pass out from it in expiration, it will sometimes traverse the nasal fossæ, and sometimes the mouth; the position that the veil of the palate assumes, on these occasions, deserves attention. When the air traverses the nasal fossæ, and the pharynx, to enter into the larynx, or to pass out from it, the veil of the palate is vertical; and applied to the anterior surface of the posterior part of the base of the tongue, so that the mouth has no communication with the pharynx. When the air traverses the mouth, in inspiration or expiration, the veil of the palate is horizontal, its posterior edge embraces the concave surface of the pharynx;

and all communication is stopped between the inferior part of the pharynx and the superior part of this canal, as well as the nasal fossæ. Hence the necessity of requesting patients to breathe through the mouth, if we wish to inspect the tonsils or the pharynx.

These two ways by which air arrives at the glottis are necessary, and, occasionally, supply each other's place. Thus, when the mouth is filled with aliment, the respiration is made through the nose; and it takes place through the mouth when the nasal fossæ are obstructed by mucus, a slight swelling of the pituitary membrane, or any other cause. At the moment of inspiration the glottis opens and contracts, on the contrary in expiration. It appears that the number of inspirations made in a given time, differs essentially in different individuals. Hale states that there were twenty in the space of a minute. A man upon whom Menzies experimented, breathed but fourteen times in a minute. Sir Humphrey Davy informs us that he respired twenty-six or twenty-seven times in that space. Mr. Thompson says, that his ordinary breathing is nineteen times in a minute; but I breathe myself fifteen times in the same period. Taking twenty, then, as the medium, we shall have 28,800 inspirations in twenty-four hours. But it is probable that this number will vary very much from a variety of circumstances. Such as the duration of sleep, motion, distention of the stomach by aliment, the capacity of the chest, and the moral affections.

What quantity of air, it may be inquired, enters into the chest at each inspiration? What quantity passes out at each expiration? And how much remains there habitually?—According to Menzies, the medium quantity of air, which enters into the lungs at each inspiration, is three hundred and twenty cubic inches. Goodwin thinks that, after a complete expiration, the lungs still contain about eight hundred and eighty cubic inches. Menzies asserts, that the quantity is much greater, and that it amounts to fourteen hundred and sixty-one cubic inches.

According to Davy, after one strong expiration, his lungs retain three hundred and thirty-two cubic inches.

After a natural expiration,	970 cub. in.
After a natural inspiration,	1106
After a strong inspiration,	3206
By strong expiration, after a deep inspiration, there passed out from the lungs,	1556
After a natural inspiration,	643
After a natural expiration,	353

Mr. Thompson thinks that we shall not be far from the truth, if we suppose, the quantity of air, generally contained in the lungs, to be 2294 cub. in. and that there enters, and passes out of the chest, at each expiration and inspiration, 327 cub. in. Thus, supposing twenty inspirations in a minute, we should have entering and passing out from the lungs in this time, 6500 cub. in.; and in twenty-four hours, 75556 cub. in. or nearly 48 pounds.

Chemists have made a great number of experiments to determine, whether the volume of air diminishes during the time it remains in the lungs. From the most recent experiments it appears, that, in the greater number of instances, no diminution is observed; that is, the air expired represents exactly the same volume as that inspired. When this diminution has taken place, it appears to have been purely accidental.*

In traversing, successively, the mouth, or nasal cavities, the pharynx, the larynx, the trachea and the bronchiæ, the inspired air acquires a temperature nearly equal to that of the body. Having become heated, and of consequence rarefied, the same quantity of air in weight, occupies a much greater space in the lungs, than before it was introduced into this viscus. Besides this change in volume, the inspired air becomes loaded with the vapour, which is continually thrown off from the mucous membrane of the lungs; it is, therefore, not only warm, but humid, when it arrives at the pulmonary cells; finally, the portion of air, of which we have spoken, becomes mixed with that which the lungs before contained. But expiration soon succeeds inspiration, a few seconds, ordinarily intervene; the air that the lungs contain, compressed, by the expiratory powers, escapes in an inverse ratio to the air inspired. It is proper here to remark, that

* See Thompson's Chemistry.

the portion of air expired is not, identically, that which had been just inspired; but is a portion of the mass which the lungs contained before inspiration. If we compare the volume of air that the lungs habitually contain, with that inspired and expired at each respiration, we shall be induced to believe, that the end of inspiration and expiration, is but to renew, in part, the large mass of air contained in the lungs. This renewal will be much more considerable, when the quantity of air expired is very great, and the succeeding inspiration strong.

Physical and Chemical changes that the Air undergoes in the Lungs.

The air passes out from the lungs, at about the same temperature with the body; a great quantity of vapour, called pulmonary transpiration, escapes with it; its chemical composition, is different from that of the air inspired. The proportion of azote is nearly the same, but the quantity of oxygen and carbonic acid, are essentially different. Instead of twenty-one parts of oxygen, and one of carbonic acid, in one hundred, which the atmospheric air presents, the expired air is found to contain eighteen or nineteen parts of oxygen, and three or four of carbonic acid. In general, the quantity of carbonic acid, represents exactly the quantity of oxygen that has disappeared; the last experiments, however, of Gay Lussac, and Davy, shew a small excess of acid, that is, a little more carbonic acid is formed, than oxygen disappeared. To estimate the quantity of oxygen consumed by an adult in twenty-four hours, it is only necessary to recollect the quantity of air respired during this interval. According to Lavoiser, and Davy, two hundred and fifty-six cubic inches are consumed in one minute, which gives, in twenty-four hours, two thousand nine hundred and eighty cubic inches.

It is not difficult to appreciate the quantity of carbonic acid that passes out from the lungs at the same time, inasmuch as it is nearly equal to the volume of oxygen that has disappeared. Thompson estimated it at three hundred and twenty cubic inches; though it may be, he remarks, probably less. Now this quantity of carbonic acid, represents about five thousand two hundred and seventy grains of carbon. Some chemists say, that a small quantity of azote disappears during respiration; others have thought, on the contrary, that the quantity of this gas was sensibly increased; but there is nothing positively known on this point. We are informed of the degree of alteration that the air undergoes in our lungs, by a sensation which impels us to renew it. This is hardly perceptible, in common respiration, because we hasten to obey this impulse; but it becomes extremely painful, if this sensation be not satisfied; it soon causes anxiety and fear, which are instinctive evidences of the importance of respiration. While the air contained in the lungs is thus modified, both in its physical and chemical properties, the venous blood traverses the ramifications of the pulmonary artery, which form, in part, the tissue of the cells of the lungs. It then passes into the ramifications of the pulmonary veins, and soon into the veins themselves; during this, the nature of the blood becomes changed, from venous to arterial blood. Let us now examine the phenomena of this transformation.

Change of the Venous, into Arterial Blood.

At the moment when the blood passes through the minute vessels, which cover the pulmonary or air cells, it assumes a bright scarlet colour; its odour is stronger, its taste more distinct, and its temperature elevated about one degree. One part of the serum escapes in the form of vapour, into the air cells, and mixes with the air. Its tendency to coagulate, sensibly augments. This fact is generally expressed by saying its *plasticité* is much greater; its specific gravity, and its capacity for caloric, are both diminished. When the venous blood has acquired these characters, it becomes arterial. In order that we may render more evident, the differences between arterial and venous blood, we shall recapitulate them in the following table.

Principal differences between Venous and Arterial Blood.

	Venous Blood.	Arterial Blood.
Colour,	a modena red,	bright scarlet.
Odour,	weak,	strong.
Temperature,	98° Far.	nearly 100.
Capacity for caloric,	852*	839
Specific gravity,	1051*	1049
Coagulation,	less prompt,	more prompt.
Serum,	more abundant,	less abundant.

I have already described the changes that the air undergoes in the lungs; and am now about to notice those which take place in the venous blood, in traversing these organs; let us now see what connexion exists between these two orders of phenomena. The colour of the blood evidently depends upon its mediate contact with the oxygen; for, if any other gas exists in the lungs, or if the atmospheric air be not renewed, this change in colour no longer takes place. But it manifests itself anew, as soon as we permit the introduction of oxygen gas into the air cells of the lungs. It is easy to see the phenomenon of the change in colour of the venous blood, even in the dead subject. At the approach of death, the venous blood often accumulates in the vessels of the lungs; the bronchiæ being deprived of air, it preserves the venous properties long after death. If the atmospheric air be forced into the trachea, in such a manner as to distend the tissue of the lungs, it causes a change of colour in the blood, from the modena red to a bright vermilion tint.

The same phenomenon is observed whenever the venous blood is brought in contact with oxygen, or atmospheric air. Blood drawn from a vein and exposed to the air, assumes a brighter tint; immediate contact is not necessary; the same blood contained in a bladder, and plunged into oxygen gas, becomes scarlet over its whole surface. Thus, the very delicate vascular walls which, in the lungs, separate the atmospheric air, and the blood, cannot be considered as an obstacle to this change of colour. But, it may be inquired, how does oxygen gas produce this change of colour in the venous blood?—Chemists are not agreed upon this point. Some think that it combines directly

* Water being as 1000.——J. Davy.

with the blood; others, that it removes from the blood a certain quantity of carbon; and there are others again, who are inclined to believe, that both these effects take place; but neither of these explanations will satisfactorily account for the change of colour. Many chemists have attributed the peculiar colour of the blood to the presence of iron, but this opinion is now rejected as extremely doubtful; it will, however, seem less unreasonable, when it is recollected, that if this metal be separated from the coloured part of the blood, it loses the property of becoming scarlet, on being exposed to oxygen gas.*

We may easily imagine the loss of serum which the blood undergoes in respiration. It is very probable, that a certain quantity of serum escapes from the extreme ramifications of the pulmonary artery, and evaporates into the air which the cells contain. This vapour afterwards passes out with the expired air, under the denomination of pulmonary transpiration; but it does not necessarily follow, that all the vapour which passes out from the blood, during expiration, arises from the pulmonary artery. I have remarked above, that a considerable portion of this vapour is thrown off by the arterial blood, which is distributed to the mucous membrane of the bronchiæ. In his first researches upon respiration, Lavoisier believed, that a combination of hydrogen and oxygen took place in the lungs, from which resulted the formation of a certain quantity of water; and that this water formed a part of the pulmonary transpiration. This idea, however, is not at present admitted; but this transpiration is considered as the result of the passage into the air cells of a part of the fluid which passes through the pulmonary artery. Anatomy seems to confirm this; water injected into the pulmonary artery, passes, under the form of innumerable small drops almost imperceptible, into the air cells, and mixes with the air which they contain.

In living animals, we may increase, at will, the quantity of pulmonary transpiration, by injecting distilled water at the temperature of the body, into the venous system, as the following experiment will prove. Take a small dog, and inject, at different

* We must not confound the colouring matter of the blood, described by Messrs. Brande and Vauquelin, with *hæmatine* the colouring matter of logwood, which was discovered by M. Chevreul.

times, a considerable volume of water; the animal will at first be in a perfect state of plethora, its vessels will be so completely distended, that it will move with difficulty; but, at the end of some moments, its respiration will become considerably accelerated, and there will be poured out a great abundance of fluid from the throat, the source of which is evidently the pulmonary transpiration, considerably augmented. It is not only the aqueous part of the blood, which escapes by pulmonary transpiration. I have shewn, by direct experiments, that many substances introduced into the veins, either by absorption or direct injection, soon pass out by the lungs. Diluted alcohol, a solution of camphor, of æther or odoriferous substances, introduced into the cavity of the peritoneum, or any other part, are soon absorbed by the veins, and transported to the lungs, pass into the bronchiæ, and may be recognized by the peculiar odour of the expired air.

Phosphorus acts in the same manner, its odour is not only sensible in the expired air, but its presence is still more easily shown, and in the most positive manner. Inject into the crural vein of a dog, half an ounce of oil, in which phosphorus has been dissolved, you will scarcely have performed this operation, when there will issue from the nostrils of the animal, a dense, white vapour which is the phosphoric acid. It appears, from the experiments of Dr. Nysten, that gases act in nearly the same manner; that is, that after they have been injected into the veins, they pass out with the expired air.

Some attempts have been made to determine the quantity of vapour that escapes from the lungs of an adult, in twenty-four hours. The latest, performed by Mr. Thompson, fix it at about eighteen ounces; Lavoisier and Seguin, formerly estimated it at something less than this. It is probable, that it is varied by an infinite number of circumstances.

It is not yet, considered as settled, in what mode the carbonic acid contained in the expired air, is formed. It is thought by some that it exists, ready formed, in the venous blood, and that it is exhaled by this fluid, at the moment of its passage through the lungs; by others, that it is the result of the direct combination of the carbon of the venous blood with the oxygen; but neither of these opinions can be considered as fully established; perhaps both these effects may take place at the same time. From our ignorance of the mode of formation of the carbonic acid, we are unable to fix the precise part performed, by the oxygen in respiration. Some assert that it is employed to combine with the carbon of the venous blood; others, that it passes into the pulmonary veins, and there is still another class who believe that it performs both these offices, at the same time. All this part of animal chemistry requires further investigation; so long as we have not any positive knowledge concerning the formation of carbonic acid, and the disappearance of oxygen, it will be difficult to determine the cause of the elevation of temperature, which takes place in the blood, in passing through the lungs. It is probable, however, that the oxygen combines with the carbon of the blood, and, as every formation of this kind is accompanied by a considerable evolution of caloric, it is probable, that this is the cause of the increased heat of the arterial blood. If we suppose, also, that the oxygen is absorbed, passes into the pulmonary veins, and that it combines afterwards directly with the blood; we may then account for the elevation in the temperature of the blood; for every combination of oxygen with a combustible body, is accompanied with an evolution of caloric.*

The slight diminution in the specific gravity of the blood, and its capacity for heat, arises, probably, from the loss of water, from the surface of the air cells. With respect to the other properties that the venous blood acquires in traversing the lungs, such as its odour, peculiarity of taste, &c. that our opinions on this point may be accurate, it is necessary that an exact and comparative analysis of the venous and arterial blood, should make us precisely acquainted with these differences. This is a service, for which physiology looks to the science of chemistry.

Respiration of other Gases than Atmospheric Air.

We must not rest satisfied with studying the effects of the respiration of atmospheric air; we are naturally desirous of knowing what would be the result of the respiration of other kinds of gas. Animals have been plunged into them, and men have voluntarily or involuntarily respired them, it is thus known, that

* See article, animal heat.

atmospheric air alone can serve the purposes of respiration, for any considerable time. Every other gas destroys animal life, more or less promptly; oxygen itself, when respired pure, is fatal, and even when it is mixed with azote, in proportions different from the common air, it, sooner or later, causes the death of those animals that respire it. From these facts, we are induced to divide gases, as they relate to respiration, into two classes;—first, those which are respirable; second, those that are deleterious.

The first, to which belong the protoxide of azote, hydrogen, &c. destroys animals, only, because they are incapable of fulfiling the office of oxygen. Among these gases there is one, the protoxide of azote or nitrous oxide, which produces very remarkable effects, and which may perhaps be considered as belonging to the second class. Sir. H. Davy was the first who examined the effects of this upon himself. After having expired the air from his lungs, he breathed about five pounds of the nitrous oxide; the first sensations which he experienced were those of vertigo; at the end of about half a minute, continuing still to respire this air, these effects gradually diminished; and were succeeded by a sensation analogous to a gentle pressure, over all the muscles, accompanied by a slight, but very agreeable trembling, particularly in the chest and extremities. Surrounding objects appeared to him of a dazzling brightness, and his hearing to become more acute; towards the last, the agitation augmented, his muscular force seemed much increased, and he felt an irresistable propensity to put himself in motion. These effects diminished, as soon as he had ceased to respire the gas, and, in the course of ten minutes, he found himself in a natural situation.

The effects are not, however, always the same; Vauquelin and Thenard, who also respired this gas, did not perceive all the phenomena described by Davy, but others analogous to them. The deleterious gases are those which are not only incapable of respiration, but destroy, more or less rapidly, men and animals which respire them, even when mixed with certain portions of atmospheric air. Of this number are all the acid gases, ammoniacal gas, sulphuretted hydrogen, &c. &c.

Influence of the Nerves of the eighth pair upon Respiration.

The nerves of the eighth pair are the only cerebral nerves which send filaments to the tissue of the lungs; this has induced physiologists to divide them, to ascertain the effects that would result from it. This easy experiment was made often by the ancients, and there are few modern physiologists who have not repeated it. Every animal, in which the nerves in question are divided, dies more or less suddenly; sometimes, death takes place instantly after the division. It never survives more than three or four days. Death has been attributed, by authors, in turn, to the cessation of the motions of the heart, imperfect digestion, inflammation of the lungs, &c. We are indebted to the recent inquiries of Messrs. Dupuytren, Dumas, Blainville, Provencal, and Legallois for the interesting information they have given us on this subject. I will now present an abstract of their researches.

A division of the nerves of the eighth pair, in the neck, on a level with the thyroid gland, or even lower, has an influence; first, upon the larynx; second, upon the lungs. These two classes of effects must be distinguished. In treating of the voice, we have said, that the division of the recurrent nerves, produced a sudden loss of the voice. The same phenomenon takes place after the division of the eighth pair of nerves, which is easy to understand, as the recurrents are but branches of these nerves. But besides the loss of the voice, it is not uncommon, that a section of the nerves of the eighth pair, is followed by such an approximation of the lips of the glottis, that the air is incapable of penetrating into the larynx, and that sudden death happens; as is always the case in an animal, which is incapable of renewing the air of its lungs. In ordinary cases; the sides of the glottis are not brought so exactly in contact, as to entirely prevent the air from entering into the larynx, for the purposes of respiration. But, as the glottis has lost its peculiar motion, the air enters into, and passes out from the chest, in a more irregular and constrained manner.

At the time when these observations were made, it would have been impossible to have explained, satisfactorily, these different phenomena. But as the reader is now acquainted with the manner in which the recurrent and laryngeal nerves are distributed to the muscles of the larynx; the subject presents no further difficulty. By the division of the eighth pair at the lower part of the neck, the dilator muscles of the glottis are parayzed. This opening no longer enlarges itself at the instant of inspiration, while the constrictors, which receive their nerves from the superior laryngeal, preserve their action and close the glottis, more or less completely. When the section of the eighth pair is not followed by such a constriction of the glottis as to cause instantaneous death, other phenomena are developed, and death does not occur until the end of three or four days.

Respiration is at first constrained, the motion of inspiration is more extensive and frequent, and the animal seems to pay a particular attention to it; he is not inclined to move, is evidently fatigued by exertion, and will often preserve a perfect state of repose. The formation of arterial blood is not prevented, for a short time after the operation; but soon, the second day for example, the laborious respiration increases, and the efforts in inspiration become greater. The arterial blood has no longer the vermilion tint which is peculiar to it, it becomes deeper coloured, and its temperature diminished; at last all these symptoms increase, respiration can only be effected by the action of all the inspiratory muscles; the arterial blood becomes of a dull red, and similar to venous blood; the arteries containing but little of it, a chilliness becomes manifest, and the animal soon dies. On opening the chest we find the bronchiæ, and sometimes the trachea itself, filled with a frothy fluid, sometimes bloody; the tissue of the lungs is engorged and swollen; the ramifications, and even the trunk, of the pulmonary artery, are distended with blood of nearly a black colour; there is likewise found a considerable effusion of serosity, or even of blood, into the parenchyma of the lungs. On the other hand, experiments show, that, in proportion as this series of phenomena becomes developed, the animals consume less oxygen, and form a less quantity of carbonic acid. It has been supposed, with reason, that, in this case, the animals perish because respiration cannot be performed, the structure of the lungs being so altered, that the inspired air cannot arrive at the air cells. I think we may add to this cause the difficulty which the blood from the pulmonary artery, experiences in passing into the vein; a difficulty which appears to me to be the cause of the distention of the venous system after death, and of the small quantity of blood which the arterial system contains, sometime before this event happens.

The section of one of the nerves of the eighth pair, produces these effects upon one of the lungs only, and life may be continued by the action of the other of these organs, the animal not perishing. I have seen animals live in this state many months.

Of Artificial Respiration.

The principal object of the motion of the thorax, is to draw air into the lungs, and afterwards to expel it from these organs. Whenever these motions are stopped, the air of the lungs being no longer renewed, respiration necessarily ceases, and death soon follows. But we may supply, for a certain time, the action of the thorax, by introducing air artificially into the lungs. Both ancient and modern anatomists have often practised this. The air has been gradually introduced with bellows, or bladders, &c. This may also be done with a syringe, with a small hole on the side of its tube. The end of the tube is introduced into the trachea, and fixed there by a ligature; afterwards we draw the piston, in order to fill the syringe with air; we then apply one finger upon this small hole, to prevent the air from passing out through it; the piston is then forced down, and the air of the syringe passes into the lungs. We then withdraw the piston, and the syringe becomes filled with air from the lungs; we now raise the finger placed upon the small hole, and, by pushing down the piston, cause the air to escape, which has already performed the purposes of respiration; we draw immediately the piston, to fill the instrument with pure air, leaving the little hole open, &c. By repeating regularly these motions, we are enabled to protract the life of an animal, in which the thorax has become immoveable, either from a division of the spinal marrow, behind the occipital bone, or even where the head has been entirely cut off. It, however, fulfils but very imperfectly the function of respiration, and can never be prolonged beyond a few hours. Frequently the lungs become engorged by the blood, or are torn by the air; this fluid is also introduced into the pulmonary veins, and spreads itself into the cellular tissue, so as to prevent the dilatation of the air cells.

COURSE OF THE ARTERIAL BLOOD.

This function has for its object, to transport the arterial blood from the lungs to every part of the body.

Of the Arterial Blood.

From what has been already said of the arterial blood, under the article respiration, there remains for us but little to add respecting this fluid. It will be proper to observe, that the learned Professor Vauquelin has recently found in this fluid, a considerable quantity of oily matter, of a yellowish colour, of a bland taste, and of a soft consistence, and which, of consequence, in appearance at least, has great analogy to fat. When, by the aid of a strong magnifying glass or microscope, we examine the transparent parts of cold blooded animals, we discover, in the sanguineous vessels, an innumerable multitude of small rounded particles, which swim in the serum, rolling one over the other, as they pass from the arteries to the veins.

Similar observations have never been made upon warm blooded animals, because the membranes and walls of the sanguineous vessels are opaque. But, as by diluting a drop of blood with water, we can distinguish, by means of a microscope, particles of a rounded form, the existence of globules has been admitted, both in animals and man. Very wonderful things have been said of these globules. According to Lewenhoeck, a thousand millions of these globules are not larger than a grain of sand. Haller, in speaking of cold blooded animals, (for he had never seen these globules in warm blooded,) says, they are $\frac{1}{5000}$ part of an inch in diameter. Some have thought, that they were of the same diameter and form in all animals; others, on the contrary, have maintained that they have a peculiar size and form in each animal; some say, that they are spherical, and whole; others, that they are flattened, with a hole pierced through their centre; finally, there have been some, who have thought that a globule, was a small bladder which contained a certain number of small globules.

I think there is much of fancy, error, and optical illusion, in all these different opinions. I have made a great number of microscopic experiments, to clear up this point. I have never seen, in the blood of man diluted in water, any thing more than particles of coloured matter, generally rounded and of different sizes, which, accordingly as they were placed accurately or otherwise in the focus of the microscope, appeared sometimes spherical, sometimes flattened, and at others, as if they were pierced through the centre. All these appearances may be produced, at pleasure, by varying the position of the particles, in relation to the instrument. I believe also, that air bubbles have been often described and designed in books, for globules of blood. Nothing, at least, resembles more certain figures of Hewson, for example, than small bubbles of air, which may be produced by agitating slightly the fluid submitted to the microscope.

Apparatus of the Arterial Blood.

It is composed first, of the pulmonary veins, second of the left cavities of the heart, third, of the arteries.

Pulmonary Veins.

They arise like the other veins, in the tissue of the lungs; that is, they consist at first of an infinite number of small branches, which appear to be a continuation of the pulmonary artery; these branches uniting, form small trunks, which gradually become larger. At last, all these trunks terminate in four vessels, which, after running a short distance, open into the left auricle of the heart. The pulmonary veins differ from all other veins in this, that they do not anastomose with each other when they have acquired a certain size. We have observed a similar disposition in the divisions of the artery, which is distributed to the lungs. The pulmonary veins have no valves, but their structure, in other respects, is similar to the other veins; their middle membrane is, however, a little thicker, and seems to possess a greater degree of elasticity.

Left cavities of the Heart.

The form and size of the left auricle differ but little from the right, its surface only is smoother, and does not present any fleshy column, (except in the appendix called *oricule.*) It communicates, by an oval opening, with the left ventricle, which is distinguished from the right, by the greater degree of thickness of its walls, and the number, volume, and disposition of its fleshy columns. The opening by which the auricle and ventricle communicate, is garnished by what is called the mitral valve, which is very analogous to the tricuspid. The ventricle gives origin to the artery called the aorta; the orifice of which presents three semi-lunar valves, very similar to the pulmonary artery.

Of the Arteries.

The aorta is to the left ventricle, what the pulmonary artery is to the right, though it differs in many important particulars. Its capacity and extent are much greater; nearly all its divisions are considered as arteries, and have each received particular names. Its branches anastomose with each other in various modes; they often present numerous and remarkable flexuosities. They are distributed to every part of the body, and effect, in each, a peculiar arrangement; they communicate with the veins and lymphatic vessels. In other respects, the structure of the aorta strongly resembles the pulmonary artery; its middle membrane, is however, much thicker and more elastic. Through nearly its whole extent, the aorta is accompanied by filaments, arising from the ganglions of the great sympathetic nerve. These filaments appear to be distributed to its walls.

Course of the Arterial Blood in the Pulmonary Veins.

In treating of the course of the blood in the pulmonary artery, we pointed out, how this fluid arrived at the extreme branches of this vessel. The blood does not stop there, it passes into the extreme branches of the pulmonary vein, and soon into the trunks of this vein; in its passage, its motion is gradually accelerated as it passes from the small, into the large veins. It does not run with a jerk, and is nearly of equal rapidity in the four pulmonary veins. But let us inquire what cause determines the progress of the blood in these veins? We naturally refer this to the contraction of the right ventricle, and the elasticity of the walls of the pulmonary artery. Indeed having forced the blood to the extreme ramifications of the pulmonary artery, we cannot conceive why these two causes should not continue its motion even in the pulmonary veins.

This was the opinion of Harvey, who first demonstrated the true course of the blood; but modern physiologists have found this explanation too simple. It is now generally admitted, that when the blood has arrived at the extreme ramifications of the pulmonary artery, and entered those of the pulmonary veins, or, as they are commonly called, capillary vessels of the lungs, it no longer moves from the influence of the heart, but by an action peculiar to the small vessels that it traverses. This idea of the action of the capillary vessels is extremely convenient in physiology; after the vital properties, there is nothing which more facilitates our explanation of the most obscure phenomena. Let us therefore examine it with attention; and first, has this action of the capillaries been witnessed by any observer? Does it fall within the scope of our senses? No, no one pretends to have seen it, it is only a thing supposed. But let us admit for an instant the existence of this capillary action; in what does it consist? Is it a greater or less degree of contraction by which the blood, with which they are filled, is forced forward? In contracting from their elasticity, they would undoubtedly propel the blood; but can any reason be assigned why they should direct it rather towards the veins, than arteries? Finally, when the small vessels were once emptied, how would they be filled again? This could only be, by the force of the heart propelling blood into them, or else, from their dilating in such manner as to attract this fluid from the neighbouring vessels; according to this supposition, it would be as likely to attract the blood from the veins as from the arteries. If we admit, therefore, a position, which is merely gratuitous, that the capillary vessels dilate and contract themselves alternately, we still should not be able to explain the function attributed to them. That they may perform this function, it would be necessary that each capillary vessel should be arranged in a manner analogous to the heart, that it should be composed of two parts, in which, one dilated while the other contracted itself, and that there should be between them, a valve analogous to the mitral valve. Yet even with this complicated apparatus, the course of the blood in these vessels would not be uniform.

In whatever point of view, therefore, we examine this action of the capillary vessels, it is found vague and contradictory. In reptiles in which, by the aid of a microscope, it is easy to distinguish the blood of the pulmonary artery passing into the veins, no motion can be perceived at the point where the artery terminates in the veins; the motion of the blood is nevertheless manifest, and even rapid. We must conclude then, that the capillary action of the vessels of the lungs, giving motion to the blood in the pulmonary veins, is a mere supposition, an effort of the imagination, in a word, purely hypothetical; and that the true cause of the passage of the blood into the pulmonary artery and veins, is the contraction of the right ventricle of the heart.

I am far from thinking, that the small vessels at all times, equally favour the passage of the blood; we have a proof to the contrary, at each inspiration and expiration. When the lungs are distended with air, its passage is easy, but when the chest is contracted, the lungs containing but little air, it becomes more difficult. It is besides, extremely probable, that they dilate themselves, according to the quantity of blood which traverses the lungs, and many other circumstances. I am ready to believe that, according as they are distended or contracted, they may influence the progress of the fluid that traverses them; but I cannot admit that they are capable of modifying the course of the blood, or that they are the sole agents of its motion.

The eighth pair of nerves appears to have a great influence upon the passage of the blood through the lungs. It is very probable, that it modifies the disposition of the capillary vessels of these organs; when we inject water into the pulmonary artery, in the dead body, it passes immediately into the veins; a part of it, however, escapes into the cells of the bronchiæ, where it mixes with the air and forms froth; another portion escapes, and becomes infiltrated into the cellular tissue of the lungs. After a certain time, when this infiltration has become somewhat considerable, it then becomes impossible to force the injection further into the pulmonary veins. Similar phenomena occur when, instead of water, blood is injected into the pulmonary artery.

These phenomena, as we have seen, have a great analogy, with those produced by the section of the eighth pair of nerves in living animals. The pulmonary veins are not so extensible as the other veins; they pour out, promptly, into the left auricle the blood which passes through them.

Absorption of the Pulmonary Veins.

Like the other veins, the pulmonary veins absorb, and carry to the heart, those substances which are in contact with the spongy tissue of the air cells of the lungs. It is sufficient to inspire once, air charged with odoriferous particles, in order that it may become manifest in the animal economy. The deleterious gases, medicinal substances spread through the air, contagious miasmata, certain poisons, or medicines applied to the tongue, produce effects which astonish us by their promptitude. The mode of this absorption is no better understood, than that of venous absorption generally.

Passage of the Arterial Blood through the Left Cavities of the Heart.

The mechanism by which the blood traverses the left auricle and ventricle, is the same, as that by which the venous blood traverses the right cavities of the heart. When the left auricle dilates, the blood is poured in, by the four pulmonary veins, and fills it. When afterwards it contracts itself, one part of the blood passes into the ventricle, another flows back into the pulmonary veins. When the ventricle dilates, it receives blood from the auricle, and a small portion from the aorta. When it contracts itself, the mitral valve is raised and closes the opening between the auricle and ventricle, so that the blood cannot return into the auricle; it is, therefore, forced into the aorta, pushing before it the three semi-lunar valves, with which the vessel had been closed, during the dilatation of the ventricle.

It is proper, however, to remark, that, as there are no fleshy columns existing in the left auricle, it cannot be supposed to have the same influence upon the blood, that we have supposed to be exerted by the right; and, as the left ventricle has much thicker walls than the right, it must compress the blood with much greater force, which is indispensable, from the great distance this fluid has to pass over.

Course of the Blood in the Aorta, and its Divisions.

Notwithstanding the differences which exist between this and the pulmonary artery, the phenomena of the course of the blood, are nearly the same. Thus a ligature being applied upon this vessel near the heart in a living animal, it becomes contracted through its whole extent, and the blood, with the exception of a certain quantity, which remains in the principal arteries, passes in a few moments into the veins.

Some authors have called in question the fact, of the contraction of the arteries, under these circumstances. We may demonstrate this, by the following experiment. Lay bare the carotid artery in a living animal, for several inches in extent; tie it at two different points, take with a compass the transverse dimensions of the vessel, and you will then have a portion of the artery full of blood; make into the walls of this portion of the artery a small opening, and you will immediately see the blood almost entirely pass out, darting even to some distance. Measure afterwards the size, with a compass, and you will not then doubt that the artery is very much contracted, if the prompt expulsion of the blood has not already convinced you. The experiment proves also, contrary to the opinion of Bichat, that the force with which the arteries react upon themselves, is sufficient to expel the blood they contain. I will immediately give other proofs of this. During life, this total expulsion cannot take place, because the left ventricle throws out, at every moment, new masses of blood into the aorta, and this blood replaces that which is continually passing into the veins.

Every time that the ventricle forces blood into the aorta, it is distended, as well as all its ramifications of a certain calibre. But this dilatation becomes less as the arteries become smaller, and it ceases altogether, in those which are very small. These phenomena are, as we see, the same already described in speaking of the pulmonary artery. The explanations that we then gave, may with propriety be applied here.

The polished surface of the interior of the arteries, must be very favourable to the motion of the blood; we know, at least, that it diminishes when this is removed by certain diseases; the course of the fluid becomes slower, and sometimes ceases altogether. This is probably, also, the reason why blood will not pass long through a tube, introduced into the extremity of an open artery. It is very probable, that the friction of the blood against the walls of the arteries, its adhesion to these walls, its viscid nature, &c. must have great influence upon its motion. But it is impossible, justly, to appreciate these different causes, either combined or separate. Independently of these phenomena, common to all the arteries, there are some which are peculiar to the aorta, and which depend upon the anastomoses existing between its branches, and the innumerable curvatures which are found in the greater number of them.

Whenever an artery presents a curvature, there is, every time the ventricle contracts, a tendency in it to assume a straight line, this tendency manifests itself by an apparent motion, called by some authors locomotion of the artery, and which may be considered as a principal cause of the pulse. This motion is most remarkable when it is observed near the heart, and in one of the large arteries. In the arch of the aorta, it is most apparent. It may be easily explained. One consequence to be deduced from this fact is, that it is mechanically impossible, that the windings of the artery, particularly when they are sudden, should not retard the course of the blood. Bichat is entirely mistaken in this respect, when he asserts, that the meanderings of the artery have no influence. This could not happen, he says, unless the arteries were empty, when the heart sent forward its blood to them, but, as they are constantly filled, this effect cannot take place. Now, inasmuch as each curve of the artery has such a force expended upon it, as to give the vessel a tendency to become straight, there will be, necessarily, so much less force for the motion of the fluid; and, of consequence, its motion will be retarded by these curvatures.

It is much more difficult to explain the influence of the different anastomoses. Their utility is very evident; through them the arteries mutually supply each other, and distribute blood to the organs; but we are unable to say, with accuracy, what influence they exert upon the progress of the blood. If the dimensions, curves, and anastomoses of the arteries essentially modify the course of the blood, it is impossible, that all the organs, in which each of these circumstances exist in different degrees.

should receive the blood, with the same degree of rapidity, and, of consequence, with the same force. The brain, for example, receives four large arteries for itself alone; but these arteries run in a very tortuous direction, with many sudden turns, before they penetrate the cranium; when they have arrived there, they anastomose very frequently; and finally, they do not enter into the tissue of the organ until they have become extremely small. The blood must, therefore, circulate but very slowly in this organ. The kidney, on the contrary, has but one artery, which is short and voluminous, which at once buries itself in its parenchyma, and is divided into large branches; the blood must, therefore, pass through it with great rapidity.

Thus, by all the concurrent circumstances which modify the course of the arterial blood, it becomes resolved into a very complicated hydraulic problem, viz. The continued distribution of a fluid, varying essentially in quantity and rapidity in different parts, through a single system of tubes, of unequal capacity, by means of a single agent of alternate impulsion.

In the number of phenomena exhibited in the course of the arterial blood, we have placed the dilatation and contraction of the arteries. Bichat does not admit the existence of these phenomena. This author will not allow, that the arteries dilate at the instant when the ventricle contracts; and he formally denies, that they contract, to force the blood into the different parts. I think, however, that with a little attention, it is possible to see, distinctly, these two phenomena, when the artery is divided. They are, for example, evident in the large arteries, such as the thoracic, and abdominal aorta, especially in large animals; but to render them apparent upon smaller arteries, we may make the following experiment. Lay bare the crural artery and vein of a dog, to a certain extent; then pass behind these two vessels, a ligature, which must be drawn very tight over the posterior part of the thigh. The arterial blood will thus be prevented from arriving at the limb, except through the crural artery, and can only return through the crural vein. Measure with a compass, the diameter of the artery, afterwards, press it between the finger and thumb, so as to intercept the blood, and you will see, in a short time, that part of the artery which is beyond the fingers, become emptied of the blood which it contained. Allow the blood afterwards to penetrate into the artery, by removing the compression, you will then see it again become distended with blood, at each contraction of the ventricle, and resume its former dimensions.

But, though I consider the contraction and dilatation of the arteries, as a point completely ascertained, I am far from thinking, with some authors of the last century, that they dilate themselves, or that they are contracted by muscular fibres. I think, on the contrary, that they are passive in both cases; that is, that their dilatation and contraction, are simply the effects of the elasticity of their walls, acted upon by the blood, which is continually forced into their cavity, by the contraction of the left ventricle of the heart.

There is a difference in this respect, between the large and small arteries; I have proved by direct experiments, that the arteries do not exhibit any evidences of irritability; that is, they remain immoveable under the application of pointed instruments, caustics, and a stream of the galvanic fluid. Not being able to detect the contractility of the walls of the arteries, Bichat thought it necessary to deny the important phenomenon which he supposed to be the effect of it. He did not believe, that the blood ran on in a continued stream in these vessels, but he supposed that the entire mass of fluid was displaced at the instant that the ventricle contracted, and was immoveable when it was in a state of relaxation, as would happen, if the walls of the arteries were inflexible. This opinion has been supported very recently by Dr. Johnson, an English physician. He has even constructed a machine, which, according to him, renders this thing evident. But it is sufficient, to open the artery in a living animal, to see that the blood will pass out in a continued stream, with a jerk if the artery be large, and uniformly if it be small. Now, the action of the heart being intermitting, it is impossible that it should produce a continued stream. The arteries must therefore act upon the blood.

The elasticity of the arterial walls, has the effect of a reservoir of air in certain pumps, which act alternately, and which therefore, furnish the fluid in a continued stream. We know, in general, in mechanics, that every intermitting motion may be changed into a continued one, by employing the force that produce it, to compress the receiver, which reacts in a continued manner.

Passage of the Arterial Blood into the Veins.

When an injection is forced into an artery in the dead body, it returns promptly by the corresponding vein. The same thing takes place, and with still greater facility, if the injection be made into the artery of a living animal. In cold blooded animals, by the aid of a microscope, we can distinguish the blood passing from the arteries into the veins;* the communications between these two kinds of vessels is then, direct and extremely easy. It is natural to suppose that when the heart has forced the blood into the extreme arteries, that it continues to give it motion, after it has reached the branches, and even the trunks of the veins. Harvey, and a great number of distinguished anatomists have thought the same. Bichat has of late opposed, with great force, this doctrine; and has endeavoured to fix limits to the influence of the heart. He supposes that this action ceases at the point where the arteries terminate in the veins. According to him, the action of these small vessels alone is the cause of the motion of the blood.

We have already combatted this supposition, in speaking of the course of the blood in the lungs; the same reasoning applies perfectly here. Bichat asserts that this capillary action consists in a "*kind of oscillation or insensible vibration of the walls of these vessels.*" Now I ask how *an oscillation or insensible vibration of the walls* can determine the motion of a fluid contained in a canal? Again, if this vibration be *insensible*, who can undertake to decide upon its existence? Let us not, therefore, render complicated, a simple question, by a supposition vague and destitute of proof; but let us admit an explanation which presents itself naturally to the mind; viz. that the contraction of the heart, is the principal cause of the motion of the blood, both in the arteries and veins.

The following experiments, appear to me, to render this phenomenon very evident. After having passed a ligature about the thigh of a dog, in the mode just pointed out, that is, without

* Cowper asserts, that he witnessed the same phenomenon in warm blooded animals; I have repeated his experiments without success.

including either the crural artery or vein, apply a ligature, separately, upon the vein near the groin, and make a slight puncture in the vessel; the blood will then escape, forming a jet. Press then the artery between the finger and thumb, so as to prevent the arterial blood from passing to the limb; the jet of venous blood will not stop instantly, but it will continue for a few moments. At last, however, the column will diminish, and finally stop, though the vein may be full through its whole extent. If, during the production of these phenomena, we examine the artery, we shall see that it becomes gradually contracted, and at last completely empty. At this period of the experiment, let the compression upon the artery be removed, and the blood, being propelled by the heart, will soon arrive at the extreme ramifications of the artery; the column of blood will now be soon seen, to pass out from the opening in the vein, and, by degrees, the jet will become perfectly established as before. Compress anew the artery, until it becomes empty, afterwards allow the blood to penetrate slowly. Under these circumstances, the blood will continue to pass out in a small stream from the vein, but not in a jet, which will, however, take place, when the artery is left entirely free. Analogous results may be obtained, by forcing an injection of warm water into the artery, instead of allowing the blood to penetrate it; the more force used in pushing forward the injection, the more promptly will the fluid pass out from the vein.

I observed, in speaking of the lymphatic vessels, that they communicate with the arteries, and that injections pass readily from one into the other. This communication becomes still more evident when we inject saline or coloured fluids into the veins in a living animal. I have satisfied myself often, that these substances pass into the lymphatic vessels, in the course of two or three minutes, and that their presence may easily be demonstrated in the lymph extracted from these vessels.

As long as the veins which pass out from the organs are free, the blood which arrives by the arteries, traverses their parenchyma, and is not accumulated. But if the veins are compressed, or are unable to empty themselves of the blood which they contain, this fluid, still continuing to arrive by the arteries and finding no opportunity to escape into the veins, becomes accumulated in the tissue of the organ, distends the sanguineous vessels, and augments, more or less, its volume, especially if its physical qualities be such as to favour these changes. This phenomenon may be observed in many organs, but as it is most apparent in the brain, it has been most frequently remarked there. This swelling of the brain, from an obstruction in the circulation, happens whenever the course of the blood through the lungs is interrupted; and as this takes place, generally during expiration, the brain at this moment becomes swollen, in proportion as the expiration is longer and more complete. In young animals, where the brain receives proportionally more arterial blood, the swelling is much more remarkable.

Remarks on the Motions of the Heart.

The right auricle and ventricle, and the left auricle and ventricle, the actions of which we have investigated separately, really form but one organ, *the heart.* The auricles contract and dilate themselves at the same moment; the motion of the ventricles is also simultaneous. When we speak of the contraction of the heart, it is to the ventricles that we particularly refer. Their contraction is called the systole, and their dilatation the diastole of the heart.

Every time that the ventricles contract, the whole of the heart is thrown suddenly forward, and the apex of this organ strikes against the walls of the left side of the chest, near the space between the sixth and seventh true ribs. This displacement anteriorly of the heart, during its systole, has given occasion to a long and spirited controversy. Some contend that the heart becomes shortened during its contraction; others maintain that it becomes elongated, and that this is necessarily the case, otherwise it could not strike against the walls of the thorax, inasmuch as it is more than an inch distant from it during its diastole. A great number of animals were uselessly sacrificed, in examining this motion of the heart; at the same moment, some asserted, that they saw the heart shortened, while others as strongly affirmed the reverse. What experiments could not determine, a very simple reasoning makes clear. Bossuet interfered in the controversy and showed, that if the heart were elongated in its systole, the mitral and tricuspid valves, being retained by the fleshy columns, could not close the openings between the ventricles and auricles. The partisans of the lengthening of the heart, persisted no further; but it remained to be shewn, how the ventricle could be shortened, as the heart was carried forward. Senac proved, that this depended upon three causes. First, the dilatation of the auricle, which takes place during the contraction of the ventricle; second, the dilatation of the aorta and pulmonary artery, in consequence of the blood introduced into them by the ventricles; third, the tendency in the arch of the aorta to be thrown into a straight line by the contraction of the left ventricle.

The number of pulsations of the heart is considerable, and is greatest in the early periods of life.

At birth, it is from	130	to 140	in a minute.
At one year,	120	130.	
At two years,	100	110.	
At three years,	90	100.	
At seven years,	85	90	
At fourteen years,	80	85.	
At the adult age,	75	80.	
In old age,	65	75.	
Extreme old age,	60	65.	

But these numbers vary, according to an infinite number of circumstances, such as sex, temperament, individual disposition, &c. The affections of the mind have a great influence upon the rapidity of the contractions of the heart; every one knows, that an emotion, however slight, modifies these contractions, and often accelerates them. Diseases produce great changes in this respect.

Many researches have been made, to ascertain the force with which the ventricles contract. To appreciate that of the left ventricle, an experiment has been made, which consist in crossing the legs, placing the ham of one leg upon the knee of the other and suspending, at the end of the foot, a weight of fifty-five pounds. This considerable weight, though placed at the extremity of so long a lever, is raised at every contraction of the ventricle, in consequence of the tendency to become straight, which occurs in this accidental curve of the popliteal artery, when the legs are crossed in this manner. This experiment shows, that the contractile force of the heart is very great, though it does not enable us to form any accurate estimate of it. The mechanical physiologists made great efforts to express it in numbers; Borelli, compared the force with which the circulation is carried on, to a power that would be necessary to raise a weight of 180,000 pounds; Haller supposed it to be 51 pounds 5 ounces, and Keil reduced it to five or eight ounces. Which shall we consider the truth among such palpable contradictions? It appears to be impossible to know, exactly, the force exerted by the heart, when it contracts itself. It is probable that it is varied by numerous causes, such as age, volume of the organ, size of the individual, peculiar constitution, quantity of the blood, state of the nervous system, the action of the organs, and a state of health or disease, &c. All that has been said of the force of the heart, relates only to its contraction; its dilatation has often been considered as a passive state, a sort of repose of the fibres. However, when the ventricles dilate, it is with great force, capable, for example, of raising a weight of twenty pounds, as I have often remarked in animals recently dead. When we seize with the hand the heart of a living animal, however small its size, it is impossible, whatever force we may exert, to prevent the dilation of the ventricles. The dilatation of the heart cannot, therefore, be considered a state of repose, or inaction.

From the first moment of the existence of the embryo, until death takes place from decrepitude, the heart continues to beat. What is the cause of this? This question has often been proposed, both by ancient and modern philosophers and physiologists. The causes of phenomena are not easily assigned in physiology. It almost always happens, that what are considered such, are nothing more than descriptions of these phenomena in different terms. But it is curious to remark the facility, with which we suffer ourselves to be abused in this respect; the different explanations of the motion of the heart, are most palpable proofs of this. The ancients asserted, that there was in the heart a peculiar virtue, a concentrated fire, which gave motion to this organ. Descartes imagined, that there took place in the ventricles, a sudden explosion, like that from gunpowder. The motion of the heart was afterwards attributed to the animal spirits, the nervous fluid, the *præses systematis nervosi*, and the *archeus;* Haller considered it, as an effect of irritability. Recently, M. Legallois has endeavoured to prove, by experiments, that the principal cause of the motion of the heart, had its seat in the spinal marrow.

These experiments of M. Legallois consisted in destroying, successively, in living animals, the spinal marrow, by introducing a metallic staff into the vertebral canal. The result is, that the force with which the left ventricle contracts, diminishes in proportion to the destruction of the spinal marrow, and when it is complete, the heart no longer possesses power of propelling the blood to the extremities. From these experiments, which have been multiplied and varied with great ingenuity, M. Legallois concludes, that the cause of the motion of the heart exists in the spinal marrow. As it has been remarked, that this organ continues to contract, for a considerable time after the complete destruction of the spinal marrow, and that its motions continue regular even after it has been separated from the body; M. Legallois explains these facts, by saying, that these motions are not the true contractions of the heart, that they are only the simple effects of the irritability of the organ.

To make good this explanation of M. Legallois, it would be necessary to show by experiments, in what the difference between the irritability of muscular fibres, and their power of contraction consists. This important distinction not having yet been established, I conceive, that we cannot conclude from the labours of M. Legallois any thing more, than that the spinal marrow has an influence upon the force with which the heart contracts; but we can by no means infer, that it is the cause of the motions of the heart.

The organs which transmit to the heart, the influence of the brain and spinal marrow, are nervous filaments coming from the eighth pair, and perhaps a great number of filaments of the cervical ganglions of the great sympathetic. M. Dupuytren and myself have endeavoured, for several years, to determine by the excision of the cervical ganglions, and even the first of the thorax, the influence of the ganglions upon the motion of the heart; but our efforts have been thus far unsatisfactory. The animals have nearly all died, in conse uence of the wound unavoidable in extracting them. We have never remarked any direct influence upon the heart.

Remarks on the Circulation of the Blood.

We are now acquainted with all the links that form the chain which the sanguineous system represents. We know how the blood is carried to the lungs, and to every part of the body, and how it returns again to the heart. Let us now examine these phenomena in a general manner, that we may impress the most important of them, more strongly upon our minds.

The quantity of blood contained in the sanguineous system is very considerable. It has been estimated, by many authors, at from twenty-four to thirty pounds. This estimate cannot be very exact, as the quantity must vary according to a variety of causes. We know, but little better, the difference between the mass of arterial and venous blood. The last, being contained in vessels, the capacity of which is superior to the arteries, must necessarily contain the most, though we cannot say, exactly, how much it exceeds.

The circle through which the blood passes, being uninterrupted, and the capacity of the canal being very variable, the rapidity of this fluid must be very different; because the same quantity must pass through every part in a given time, which is confirmed by observation. The rapidity is greatest in the trunk and principal branches of the aorta, and pulmonary artery; it diminishes much in the secondary branches; and still more at the point where the arteries terminate in the veins. It afterwards augments, as the blood passes from the extreme vessels into the larger trunks of the veins, but its rapidity is never as great in the venæ cavæ, as in the aorta.

In the trunks and principal divisions of the arteries, the motion of the blood is continued, not only by the influence of the elastic power of the arteries, but it is also thrown out in a jerk, by the contraction of the ventricles; this jerk manifests itself in the arteries by a simple dilatation, in those which are straight, and by a dilatation and an effort to become straightened in those which are flexuous. The first phenomenon, with which this second circumstance is connected, is the pulse. It is not easy to study this in man or animals, except at those places where the arteries run upon the bones, because there they do not move from the finger applied over them, as is the case with those which float in the midst of soft parts.

The pulse frequently makes us acquainted with the principal modifications of the contraction of the left ventricle, its promptitude, intensity, weakness, and regularity or irregularity. We know, also, by the pulse, the quantity of the blood; if it be great, the artery is rounded, large, and resisting; if little, the artery is small, and easily compressed. Certain states of the arteries influence the pulse, and may render it different in the principal arteries.

The pulsations of the arteries are, necessarily, perceptible in the neighbouring organs, in proportion as the arteries are large, and the organs yield easily. The agitation they experience, is considered favourable to their action, though there is no positive proof of this. In this respect, no organ is influenced more than the brain. The four cerebral arteries, uniting in circles at the base of the cranium, elevate the brain at each contraction of the ventricle, as may be easily seen by laying bare the brain of an animal, or by observing this organ in wounds of the head. It is probably to moderate this agitation, that the numerous curves of the internal carotid and vertebral arteries are made, before their entrance into the cranium. These flexuosities must, necessarily, retard the course of the blood through these vessels. When the arteries penetrate into the parenchyma of organs in large trunks, as the liver, kidney, &c. the organ must undergo great agitation at each contraction of the heart. The organs where the vessels do not penetrate, until they have become divided and subdivided, do not experience this.

All the blood that passes from the lungs to the left auricle of the heart, is of the same nature; it, however, sometimes happens, that it is not precisely similar in the four pulmonary veins.* If, for example, a portion of the lungs be altered to such an extent that the air cannot penetrate into its air cells, the blood, that traverses it, will not be changed from venous to arterial blood; but it will arrive at the heart without having undergone this transformation. In its passage, however, through the left cavities, it will be intimately mixed with the rest of the blood. The

* See the experiments of Legallois.

blood which goes from the left ventricle, must, necessarily, be homogeneous, until it reaches the furthest branches of the aorta; but when it arrives at the smallest vessels, its elements become separated. There exist a great number of parts, such as the serous membranes, the cellular tissue, the tendons, the aponeuroses, the fibrous membranes, &c. in which we cannot distinguish the red blood, and where the capillary vessels contain only serum. This division of the elements of the blood, is only found in a state of health. When the parts, just mentioned, become diseased, it often occurs, that their small vessels are filled with red blood.

It has been attempted, to explain this analysis of the blood in the small vessels. Boerhaave, who admitted the existence of several kinds of globules, of different sizes, in the blood, asserts, that globules of a certain size, can only pass into vessels of a given calibre. We have already seen, that the globules, as described by Boerhaave, do not exist. Bichat believed, that there existed in the small vessels a peculiar sensibility, in consequence of which, they would receive only that part of the blood adapted to them. We have already frequently combatted ideas of this kind; they are not admissible here, because the most irritating fluids, when introduced into the arteries, pass immediately into the veins, without their passage being opposed by the capillary vessels.

In traversing the small vessels, the blood is deprived of its elements; sometimes the serum escapes, and spreads itself over the surface of the membrane, at others, the fat is deposited in its cells; here it is the mucous, there the fibrine; and besides, there may be foreign substances, that have become accidentally mixed with the arterial blood. By losing these different elements, this fluid approaches the character of venous blood. At the same time that the arterial blood supplies those parts which are lost, the small veins absorb the substances in contact with them. For example, in the intestinal canal, they take up the drinks; on the other hand, the lymphatic trunks pour the lymph and chyle into the venous system. It is certain, therefore, that the venous blood cannot be homogeneous, and that its composition must vary in the different veins. But having arrived at the heart, by the motions of the right auricle and ventricle, and the disposition of the fleshy columns, all its elements become intimately mixed before it passes into the pulmonary artery.

There is a general law of the economy, that no organ can continue to act, unless it receives arterial blood; the result, therefore, is, that all the functions are dependent upon the circulation. But, in its turn, the circulation is dependent upon respiration, which forms the arterial blood; nor can it exist without the action of the nervous system, which has a great influence upon the rapidity and course of the blood, and its distribution to the organs. In fact, under the influence of the nervous system, the motions of the heart increase or diminish, and, of consequence, the general course of the blood is increased or retarded. Again, when the organs act, voluntarily or involuntarily, observation shews that they receive an increased quantity of blood, without the general circulation being at all accelerated; if their action be very considerable, the arteries leading to them have their action increased; if, on the contrary, their action diminishes, the arteries are retracted, and only allow a small portion of blood to arrive at the organ. These phenomena are manifest in the muscles; the circulation becomes more rapid when they contract; if they often contract, these arteries increase in volume; if they are paralyzed, the arteries become very small, and the pulse scarcely perceptible.

The nervous system, then, influences the circulation in three ways. First, in modifying the motions of the heart. Second, in modifying the capillaries of the organs, so as to accelerate, or retard the course of the blood. Third, in producing the same effects in the lungs, that is, in rendering more or less easy, the course of the blood through these organs. The acceleration of the motions of the heart, becomes perceptible to us, from the pulsation of its apex against the walls of the chest; an obstruction in the capillary circulation is known, by a sensation of numbness, and a particular sort of pricking. When the pulmonary circulation is difficult, we are aware of it, from a sense of oppression or suffocation. It is probable, that the distribution of the filaments of the great sympathetic nerve to the walls of the arteries, answers some important purpose, but we are completely ignorant of their use; experiment has thrown no light upon this point.

Of the Transfusion of Blood, and the Infusion of Medical Agents.

Such is the opposition that men of genius have always met from their cotemporaries, that it was thirty years before the discovery of Harvey was acknowledged, though the proofs were then most evident. But as soon as the circulation was admitted, a sort of delirium seems to have seized upon the profession; it was supposed that the means of curing all diseases, and rendering man immortal, were discovered. The causes of all our diseases were attributed to the blood. To cure them, therefore, nothing more was supposed to be required than to remove the bad blood, and to replace it with that which was pure, taken from a healthy animal.

The first attempts were made upon animals, and were very successful. A dog having lost a large quantity of blood, received, by transfusion, that of a sheep, and was perfectly restored; another dog, old and deaf, recovered, by these means the use of his hearing, and seemed to renew his youth. A horse, twenty-six years old, having received into his veins the blood of four lambs, acquired new vigour. The experiment of transfusion was now tried upon man. Denys and Emerez, the one a physician, and the other a surgeon, of Paris, were the first who made the attempt. They introduced into the veins of an insane young man, the blood of a calf, in a larger quantity than had been taken from him; he recovered his reason. A case of leprosy, and a quartan fever, were cured by these means; and many cases of transfusion were tried upon men in health, without any injurious results.

But some sad accidents soon calmed the general enthusiasm, excited by these few successful cases. The young man, soon after the experiment, became frantic; he was the second time subjected to transfusion, and soon died with a discharge of blood, and in a state of stupor. A prince of the blood royal, having also fallen a victim to this practice, it was forbidden by the parliament of Paris. A short time afterwards, G. Riva, having performed the operation of transfusion upon two individuals who died in Italy, the Pope forbade it. From that period, transfusion has been considered as not only useless, but dangerous; but as it seems to have succeeded in some cases, it would be an interesting inquiry for a person skilled in such experiments, to pursue the subject further. I have had occasion to make a certain number of these experiments, but have never known any instance where the introduction of the blood of one animal, into the veins of another, was attended by any serious inconvenience, even when the quantity of blood thus introduced, was much greater than before.

A short time after the discovery of the circulation, it was attempted to introduce medicines directly into the veins. Some advantages resulted from it in some instances, and inconveniences in others, and it soon fell into discredit; but it has been tried with success in some experiments upon animals. It is an excellent way of judging promptly of the mode of action of a medicine or poison. This process is employed in administering medicine to large animals, in the Veterinary School of Copenhagen; great benefit is found from the promptitude of its action, and great economy in the quantity of medicine employed. This mode, if used with intelligence, might be found very efficient in those extreme cases where the ordinary modes of treatment are found totally inefficient.

OF SECRETIONS.

In traversing the innumerable small vessels, by which the arteries and veins communicate, one part of the elements of the blood spreads itself over all the external and internal surfaces of the body, another is deposited in the small hollow organs, situated in the substance of the skin and mucous membranes, a third is distributed to the parenchyma of those organs called *glands*, undergoes a particular elaboration, and is afterwards poured out, under certain circumstances, on the surface of the mucous membranes or skin.

We give the generic name of *secretion*, to that phenomenon by which a part of the blood escapes from the organs of circulation, and is afterwards poured out, either externally or internally, whether it preserves its chemical properties, or whether its elements have undergone a new order of combinations. We generally distinguish the secretions into three kinds; the *exhalations*, *follicular*, and *glandular secretions*. But this division, as it respects secreting organs and secreted fluids, is very imperfect. Many organs which secrete cannot be referred either to follicles or glands; what are generally called follicles or glands, are organs which differ so much from each other in their form, structure, and the fluids they secrete, that it would perhaps be best, not to confound them under the same denomination. Nevertheless, to avoid any thing like an unnecessary spirit of innovation, we shall hereafter speak of the secretions, according to this classification. We shall not dwell on this article; for were we to allow it the extension of which it is susceptible, we should greatly exceed the bounds to which we have limited ourselves in this work.

Of the Exhalations.

The exhalations take place either within or without the body, upon the skin or mucous membranes. Hence their distinction into external and internal.

Internal Exhalations.

Wherever large or small surfaces are in contact, an exhalation takes place; whenever fluids are accumulated in a cavity, without an apparent opening, they are deposited by exhalation; the phenomenon of exhalation, also, manifests itself in almost every part of the animal economy. It exists in the serous, synovial, and mucous membranes, the cellular tissue, the interior of the vessels, and the adipose cells, the internal parts of the eyes and ears, and the parenchyma of many organs, such as the thymus and thyroid gland, and the capsulæ renales, &c. It is by exhalation, that the aqueous and vitreous humours, and the fluid contained in the labyrinth, are formed and renewed. The fluids exhaled in these different parts have not all been analysed; among those that have, many are found to resemble, more or less, the elements of the blood, and particularly the serum; such are the fluids of the serous membranes, of the cellular tissue, and chambers of the eye. Others differ more, e. g. the synovia, fat, &c.

Serous Exhalation.

All the organs of the head, chest, and abdomen, are covered with a serous membrane, which is also extended over the walls of these cavities; so that the organs are not in contact with the walls, or neighbouring viscera, except through the medium of this membrane. As this membrane is very highly polished, the organs can move easily upon each other, and upon the walls. The principal cause that preserves the fine polish, is this exhalation. There passes continually from every point of this membrane, a very thin fluid, which spreads itself over the neighbouring parts, forming a humid coat, which favours the motion of the organs upon each other.

It appears that this power of gliding upon each other, is very favourable to the action of the organs. Whenever they are deprived of this by a disease of the serous membrane, their functions are disturbed and sometimes cease altogether. In a state of health, the fluid secreted by the serous membranes, nearly resembles the serum of the blood, with a certain quantity of albumen.

Serous Exhalation of the Cellular Tissue.

The *cellular tissue* is spread over almost every part of the animal economy. It serves sometimes to separate, and at others to unite different organs, and parts of the same organ. This, every where, consists of very small delicate plates, crossing each other in a thousand different directions, so as to form cells. The size and arrangement of these plates vary, in different parts of the body. In some they are broad, thick, and form large cells; in others they are very small, thin, and form extremely small cells. In some places, this tissue is very extensible, in others it is rigid, offering considerable resistance. But, whatever may be the disposition of the cellular tissue, it exhales from its surfaces, a fluid very analogous to that of the serous membranes, and which appears to serve the same purposes. Its use is to facilitate the motion of these membranes upon each other, and, of consequence, to favour the reciprocal motions of the organs and the changes of relation in their different parts.

Adipose Exhalation of the Cellular Tissue.

Besides the serosity, we find, in the cellular tissue in many parts, a fluid of a very different nature; this is fat. As respects the presence of fat, the cellular tissue may be divided into three kinds; viz. that which contains it constantly; that which contains it occasionally; and that in which it is never found. The orbit, the sole of the foot, the ball of the fingers and toes, are always found to exhibit fat. The subcutaneous cellular tissue, and that found on the surface of the heart, loins, &c. present it often; but that of the eyelids, and scrotum, and interior of the cranium, never contain it.

The fat is contained in distinct cells, which do not communicate with the neighbouring ones. This has led to the belief, that the tissue containing the fat, differed from that containing the serum; but, as no one has yet demonstrated these fatty cells, unless when filled with fat, this anatomical distinction appears to me to be very doubtful. The size, form, and disposition of these cells, do not differ more than the total quantity of fat that they contain; in some individuals there are but a few ounces; while in others there are many pounds. From the experiments of M. Chevreul, it appears that the human fat is almost always yellow; it is inodorous, and congeals at from fifteen to twenty-five of Reaumer. It is composed of two parts, the one fluid, and the other concrete; which are again composed of two new immediate principles, but in different proportions, discovered by M. Chevreul, who calls them "*elaïne*," and "*stéarine*."

It is principally by its physical qualities, that the fat appears to be useful in the animal economy. In the orbit, it forms a sort of elastic cushion, upon which the eye moves with facility, on the sole of the foot, and the nates, it forms a cushion, which prevents the skin from being injured by the pressure of the body, in standing or sitting. It presence beneath the skin, assists in giving rotundity to the form, diminishing the projection of the bones and muscles, and thus increasing the beauty of the body. As all fatty substances are bad conductors of caloric, it is useful in this respect; fat persons seldom suffering from cold in winter. Age, and mode of life, have a great influence on the production of this substance; young infants are generally fat. It is seldom that it is much developed in youth; but after the age of thirty, especially if the food be nutritious and the mode of living sedentary, its quantity augments very much. The abdomen, at this period becomes prominent, and the nates and mammæ, in females become large. The yellow colour of this substance increases in old age.

Synovial Exhalation.

About the moveable articulations, we find a very delicate membrane, having great analogy to the serous membranes; but differing from them in having small reddish prolongations, containing numerous sanguineous vessels; they have been called *franges synoviales.* They are very visible in the large articulations of the extremities. It has been long believed by anatomists, and there are some who still think, that the capsules of the joints are folded over the moveable cartilages, and cover the surfaces to which they correspond. I have lately satisfied myself, that these membranes do not extend beyond the circumferences of the cartilages. We have spoken of the uses of the synovia, in treating of motions.

Exhalation of the Interior of the Eye.

The different humours of the eye are also formed by exhalation. They are each enveloped by a membrane, which appears to be destined to exhale and absorb them. The humours of the eye are, the aqueous humour, at present supposed to be formed by the ciliary processes; the vitreous humour, secreted by the membrana hyaloidea; the crystalline; the black matter of the choroid coat, and that on the posterior surface of the iris.

The chemical composition of the aqueous, crystalline, and vitreous humours have been explained in the article *vision.* The black matter of the iris and choroid coat, has been analysed by M. Berzelius. It is insoluble in water and acids; the caustic alkali dissolves it, and the acids precipitate it from this solution. It burns like vegetable matter, leaving a ferruginous cinder. Experience informs us, that the aqueous and vitreous humours are rapidly renewed, when pus or blood have been extravasated into the eye. In a few days they disappear, and the humours resume, by degrees, their transparency. It does not appear that the crystalline or choroid humour can be re-produced, at least nothing shows it.

Sanguineous Exhalations.

In all the exhalations that we have now considered, only a part of the principles of the blood pass out from the vessels. The blood itself appears to be poured out into several of the organs, and to fill up the cellular tissue that forms their parenchyma; such are the cavernous bodies of the vagina and clitoris, the urethra and glans penis, the spleen and the mammary processes, &c. The anatomical examination of these different tissues, seems to show, that they are habitually filled with venous blood, the quantity of which, differs in different circumstances, particularly, according to the state of action or inaction of the organs. There exist many other exhalations of internal parts, among which I would mention, the cavities of the internal ear, of the parenchyma of the thymus, and thyroid gland; and of the capsulæ renales, &c. But we are scarcely acquainted with the fluids formed in these different parts; they have never been analysed, and their uses are unknown.

Physiologists have often endeavoured to explain the phenomenon of exhalation. Indeed, each one has given his own opinion on this subject. Some admit the existence of *exhaling mouths*, others of *lateral pores*. Bichat has created particular vessels, which he calls *exhalants*. I say he has created them, for he acknowledges that these vessels cannot be seen; as the existence of these pores, mouths, and exhalants, are not sufficient to explain the diversity in the exhalations, they have been supposed to possess a peculiar sensibility, and particular motions, in virtue of which they suffer certain parts of the blood to pass, and refuse a passage to the others. We have little to remark on such explanations.

It is very certain, however, that the physical disposition of the small vessels has an influence upon exhalation, as the following facts will show. When we inject, in the dead body, warm water into an artery passing to a serous membrane, as soon as the stream is established in the artery and vein, there will be seen upon the membrane, a multitude of small drops, which evaporate promptly. Has not this phenomenon great analogy with exhalation? If we employ a solution of gelatin, coloured with vermilion, to inject a whole body, it frequently happens that the gelatin is deposited about the circumvolutions, and inequalities of the cerebrum, without the colouring matter having escaped from the vessels; the injection spreads itself, on the contrary, over the external and internal surface of the choroid coat. If we employ linseed oil, coloured with vermilion, we often find the colouring matter separated from the oil, and deposited in the synovial capsules of the large joints, while there is no transudation on the surface of the brain, or the interior of the eye.

External Exhalations.

They consist only of the exhalations of the mucous membranes, and of the skin, or cutaneous transpiration.

Exhalation of the Mucous Membranes.

There are two mucous membranes; the one covers the surface of the eye, the lachrymal passages, the nasal cavities, the middle ear, the mouth, the whole of the intestinal canal, the excretory ducts, which terminate in it, and lastly the larynx, the trachea, and the bronchiæ; the other mucous membrane covers the surface of the organs of generation, and the urinary apparatus. These two membranes are constantly lubricated by a fluid they secrete, called the *mucus*. This fluid is transparent, viscid, and of a saltish taste; it reddens litmus paper, contains much water, muriate of potash, and soda, lactate of lime, soda, and phosphate of lime. According to Fourcroy, and Vauquelin, the mucus is the same in all the mucous membranes. M. Berzelius thinks, on the contrary, that it varies much, according to the parts from which it is taken. Many persons suppose, that the mucus is formed exclusively by the follicles of the mucous membranes. I am satisfied, however, by recent experiments, that it is formed in the parts where the follicles do not exist; I have also remarked, that it continues to be formed for some time after death.

The mucus forms a covering of various degrees of thickness, on the surface of the mucous membranes, and is frequently renewed. Its water evaporates under the name of mucous exhalation. It protects the membrane from the action of the air, aliments, and various glandular fluids; it seems, indeed, to perform the same office for these membranes, as the epidermis for the skin; independently of its general uses, its functions are modified, according to the particular parts of these membranes. Thus the nasal mucus assists the sense of smell, that of the mouth facilitates taste, that of the stomach and intestines concurs in digestion, and that of the genital and urinary passages assists in the functions of generation and urinary excretion. A great part of the mucus is absorbed by the membranes which secrete it; the rest is either thrown off alone, as when we spit, or is mixed with pulmonary transpiration, fecal matter, urine, &c.

Cutaneous Transpiration.

There is a transparent fluid, with an odour more or less strong, and of a salt and acid taste, constantly passing through the innumerable openings, with which the epidermis is pierced. Most frequently, this fluid evaporates, as soon as it is brought in contact with the air, but sometimes it runs over the surface of the skin. In the first instance, it is imperceptible to the sight, it is then called *insensible transpiration;* in the second, it is called *sweat.* Whatever may be the form assumed by this fluid, when it escapes from the skin, it is composed, according to M. Thenard, of a large proportion of water, a small quantity of acetic acid, muriate of soda and potash, a little phosphate of lime, an oxid of iron, and a trace of animal matter. M. Berzelius conceives the acid of the sweat not to be the acetic acid, but the lactic acid of Scheele. The skin also exhales an oily substance and the carbonic acid.

A great number of experiments have been made, to determine the quantity of transpiration formed in a given time, and the range of its variations, under different circumstances. The first attempts of this kind were made by Sanctorious, who, for thirty years, with extreme care and unwearied patience, weighed his aliments, drinks, solid and fluid excretions, and afterwards himself. But, notwithstanding his zeal and perseverance, Sanctorious never arrived at any very precise results. Since his time, the subject has been examined with more success; the most remarkable efforts on this subject, were made by Lavoisier and Seguin. These gentlemen were the first, who distinguished between the loss from pulmonary and cutaneous transpiration. Seguin enclosed himself in an oiled cloth bag, that covered the head, with an opening for the mouth; the edges of which were made to adhere about the mouth, by a mixture of pitch and turpentine. In this way, the pulmonary transpiration alone escaped into the atmosphere. To ascertain the quantity, it it was only necessary to weigh himself with the sack, at the beginning and end of the experiment, with a very delicate balance. By weighing himself out of the sack, he determined the total quantity of the transpired humour; so that, saying nothing of the fluid which he knew had passed out from the lungs, he was in possession of the quantity of humour exhaled by the skin. He kept, besides, an accurate account of his food, solid and fluid excretions, and, in general, of all those causes that might influence transpiration.

The following are the results of the inquiries of Lavoisier and Seguin.

1. The largest quantity of insensible transpiration, including that of the lungs, is thirty-two grains per minute.

2. The least loss, was eleven grains in a minute.

3. During digestion, the loss of weight, occasioned by insensible transpiration, was at its *minimum*.

4. Immediately after dinner, the transpiration was at its *maximum*.

5. The medium quantity of insensible transpiration, was eighteen grains in a minute; of these, eleven depended upon cutaneous, and seven on pulmonary transpiration.

6. Cutaneous transpiration only varied during, and after eating.

7. Whatever might be the quantity of food taken by any one, or whatever the variations of the atmosphere, the same individual, after having increased in weight to the amount of the whole quantity of food taken, returned every day at the end of twenty-four hours, to nearly the same weight that he was before; provided, that he was not at the time growing, nor had committed any excess.

It is to be regretted, that this important undertaking was not continued, and that these authors limited themselves to the investigation of insensible transpiration, without extending their observations to the sweat. Whenever cutaneous transpiration is not reduced to vapour, as soon as it is brought in contact with the air, it appears on the surface of the skin, in the form of a liquid; now this effect may occur either from the abundance of the transpiration, or from the dissolving power of the air being diminished. We sweat readily in a warm and moist atmosphere, by the influence of these two causes, but we sweat much less easily in a warm and dry air. Certain parts of the body transpire more abundantly, and sweat more easily than others; such as the hands, feet, arm-pits, groins, forehead, &c. In general the skin of these parts receives, proportionally, a much greater quantity of blood; and some of them, the arm-pit, sole of the foot, &c. are excluded from the air. The sweat does not appear the same in every part; every one knows that its odour varies in different parts of the body, the same is true of its acidity; this appears to be much greater in the arm pits and soles of the feet, than in other parts.

Cutaneous transpiration has various uses in the animal economy; it preserves the softness of the skin, and is favourable to the sense of touch. By its evaporation, together with pulmonary transpiration, it is the principal means of cooling the body, and preserving it at a certain temperature. It would appear, that its expulsion from the economy is very important; as, whenever it is dimished or suspended, derangement of the health follows, and many diseases do not yield, until copious perspiration is produced.

Follicular Secretions.

We give the name of follicles to the small, hollow organs, lodged in the skin and mucous membranes, and which have for this reason been distinguished, into *mucous* and *cutaneous;* the follicles are also divided into simple and compound.

Mucous Follicular Secretions.

The simple mucous follicles are found over nearly the whole extent of the mucous membranes, more or less abundant; there are, however, parts of these membranes of considerable extent, where they cannot be detected. Those bodies, called the fungous papillæ of the tongue, the amygdalæ, the glands of the cardia, prostate, &c. are considered by anatomists, as collections of simple follicles. Perhaps this opinion is not well founded, we know little of the fluid they secrete, it appears to be analogous to the mucus, and to answer the same purposes.

Cutaneous Follicular Secretions.

In almost every part of the skin, there exist small openings, the orifices of small, hollow organs, with membranous walls, habitually filled with albuminous and fatty matter, the consistence, colour, odour, and even taste of which vary in different parts of the body, and are continually poured upon the surface of the skin. These small organs are called the follicles of the skin; there is at least one at the base of each hair; the hairs indeed often traverse the cavity of a follicle in passing out. The follicles form that shining fatty substance, that we see upon the scalp and cartilage of the ear. The follicles secrete the wax in the meatus auditorus externus, and likewise the thick whitish matter that we force out from the skin of the face, by pressing it, under the form of small worms. This substance, from its external surface being in contact with the air, becomes blackened, and produces the numerous spots that we see in the face of some persons, particularly about the nostrils and cheeks.

It appears also, that these follicles secrete the white, odorous matter, that is continually renewed about the parts of generation. From being spread upon the surface of the skin, hair, &c. this substance preserves the softness and elasticity of these parts, renders their surface smooth and polished, and favours their motion upon each other. In consequence of its unctuous nature, it in some measure, defends them from humidity.

Glandular Secretions.

We give the name of *gland*, to a secretory organ, which pours the fluid formed by it, over the surface of a mucous membrane or the skin, by one or more excretory ducts. The number of glands is very considerable; their action has received the name of *glandular secretion*. There are six secretions of this kind, the tears, the saliva, the bile, the pancreatic juice, the urine, the semen, and the milk. We may, perhaps, add to these the secretions of the mucous glands, and of the glands of Cowper.

Secretion of Tears.

The gland that forms the tears is very small; it is situated in the upper and outer part of the orbit, and a little on the outside of the eye; it is composed of small granulated masses, united by cellular tissue. Its excretory ducts, small and numerous, pass out at the posterior part of the upper eye-lid; it receives a small artery, a branch of the ophthalmic, and a nerve derived from the fifth pair. In health, the tears are not very abundant; the fluid is limpid, inodorous, and of a saltish taste. They were analysed by Fourcroy and Vauquelin, who found them composed of a great proportion of water, some hundredths of mucus, and muriate, and phosphate of soda; a very little soda, and pure lime. What is generally called the tears, is not entirely, however, the fluid secreted by the lachrymal gland; it is a mixture of this fluid with the matter secreted by the conjunctiva; and, probably, that of the glands of Meibomius.

The tears form a covering to the conjunctiva of the eye, and defend it from the contact of the air; they facilitate the motion of the eye-lids upon the eye, favour the expulsion of foreign bodies, and prevent the action of irritating substances upon the conjunctiva; under these circumstances, their quantity becomes suddenly very much increased. They also assist in expressing the passions; disappointment, grief, joy, and pleasure, cause the tears to be poured out in abundance; their secretion, it is manifest, is strongly influenced by the nervous system. This influence takes place, probably, through the medium of the nerve sent to the lachrymal gland from the fifth pair of cerebral nerves.*

Secretion of the Saliva.

The salivary glands are, First, the two parotids, situated before the ear, and behind the neck and ascending process of the inferior maxillary bone. Second, the sub-maxillary gland, situated beneath, and on the surface of this bone. Third, the sub-linguinal, placed immediately below the tongue. The parotids, and sub-maxillary glands, have each only one excretory duct, the sub-linguals have several. All these glands consist of granulated masses, of different forms and sizes. They receive arteries of considerable size, in proportion to their volume; and are amply supplied with nerves, derived from the brain and spinal marrow. The saliva secreted by these glands, is continually running into the mouth, and occupies its lower part. It is placed between the anterior and lateral parts of the tongue and the lower jaw, at first, and, when this space is filled, it is lodged between the inferior lip, the cheek, and the external side of the lower jaw. When deposited in the mouth, it becomes mixed with the fluids secreted by the mucous membrane and follicles.

* See for the other uses of the tears, article *vision.*

No one has ever analysed the fluid of the salivary glands separately, but only the fluid found in the mouth, which is, no doubt, almost entirely composed of saliva. It is limpid, viscid, without colour or smell, of a bland taste, and somewhat heavier than water. Berzelius asserts, that it is composed of 992.9 of water; 2.9 of a particular animal matter; 1.4 of mucus; 0.7 of muriat of potash and soda; 0.9 of tart. of sod. and animal matter, and 0.2 of soda. It is probable, that the composition of the saliva varies, as it is sometimes sensibly acid. The saliva is one of the fluids most useful in digestion; it favours the mastication and division of the aliments; it assists in deglutition and the formation of chyme; and facilitates the motion of the tongue in speech and singing. The greater part of this fluid is carried into the stomach, by the action of deglutition; a small part passes out with the expired air, and evaporates.

Secretion of the Pancreatic Juice.

The pancreas is situated in the abdomen, behind the stomach; its excretory duct opens into the duodenum, near to that of the liver. From the granulated structure of this organ, it has been considered a salivary gland; but it differs from them in the small size of the arteries it receives, and from its not having any cerebral nerve.

De Graff, the celebrated Dutch anatomist, discovered a mode of collecting the pancreatic juice; it consisted in introducing into the intestinal extremity of the excretory duct the barrel of a small quill, which terminated in a little bottle, placed in the abdomen of the animal. I have often attempted to repeat this process, but have always failed. The quill, and every other tube, wounded the mucous membrane of the duct, and the blood, oozing out, gradually closed up the mouth of the tube. I had therefore recourse to a much more simple method; having laid bare the orifice of the duct in a dog, I wiped, carefully, with a piece of fine linen, the surrounding mucous membrane, and then waited until a drop of the juice passed out. As soon as it appeared, I sucked it up by means of a peculiar sort of pipe, (*pipette,*) an instrument used in chemistry. In this way, I have been able to collect several drops of this fluid at a time, but never a sufficient quantity to make a regular analysis. I have found it of a light yellow colour, of a saltish taste, and without odour; it possessed alkaline properties, and was partly coagulated by heat.* The circumstance which has appeared the most remarkable to me, in endeavouring to procure this fluid, is the small quantity in which it seems to be formed. It frequently happens, that a drop will not pass out, once in a half hour; and I have sometimes waited for a much longer period, before it has appeared. Its secretion does not seem to be increased during digestion, but on the contrary, rather retarded. In general, I think it is most abundant in very young animals. It is impossible to form any very precise notions of the uses of the pancreatic juice.

Secretion of the Bile.

The liver is the largest gland in the body; it differs from all the other secretory organs still more, in being constantly traversed by a large quantity of venous blood, besides the arterial blood, sent to this, as to every other part. Its parenchyma does not resemble the other glands, and its secretions differ essentially from all other glandular fluids.

The excretory duct of the liver, terminates in the duodenum, but, before reaching this part, it communicates with a small membranous sac, called the *vesicula fellis;* which is almost constantly filled with bile. There are few fluids, which so materially differ from the blood as the bile. Its colour is greenish; its taste extremely bitter; it is viscid, stringy, sometimes transparent and sometimes clouded. It contains water, albumen, a substance called by chemists *resin*, a yellow colouring principle, soda, and salts, viz. muriate, sulphate, and phosphate of soda, phosphate of lime, and oxide of iron. These properties are particularly found in the bile contained in the gall bladder. That which passes directly from the liver, and which is called the hepatic bile, has never been analysed. It is not of so deep a colour, is less viscid, and less bitter than the cystic bile. The formation of bile seems to be continual. Whatever may be the circumstances in which the animal is placed, if the orifice of the duct, called the ductus communis choledochus, be laid bare, we can distinguish

* In birds, which have two organs of this kind, I have remarked that the excretory ducts are endowed with a constant peristaltic motion. The pancreatic juice is also much more abundant; it is almost entirely albuminous, at least it hardens, like albumen, by heat.

this fluid, passing drop by drop over the surface of the intestine. It appears that the gall bladder becomes filled, when the stomach is empty and the abdominal pressure least. It has always appeared to me to be more distended at this time, but it does not lose all its contents when the stomach is full. The circumstance which contributes most to the expulsion of the bile, is vomiting. I have often found it empty in animals which have died in consequence of poisons producing vomiting.

The liver receiving, at the same time, venous blood by the vena portæ and arterial blood by the hepatic artery, physiologists have found great difficulty in determining which, of these two sorts of blood, serves for the secretion of bile. Some have thought that the blood of the vena portæ, having more carbon and hydrogen than that of the hepatic artery, was more suitable for furnishing the elements of the bile. Bichat has opposed this opinion with success; he has shown, that the quantity of arterial blood sent to the liver, bears a nearer proportion to the quantity of bile formed, than the venous blood; that the size of the hepatic duct is not in proportion to the vena portæ; and that the fat, a fluid containing much hydrogen, is secreted from the arterial blood, &c. He might have added, that nothing proves the blood of the vena portæ to be more analogous to the bile than the arterial blood. We shall not take a part in this controversy; the two opinions are equally destitute of proof. Besides, it is not improbable that both sorts of blood may serve the purposes of secretion. Anatomy seems to prove this; for injections show that all the vessels of the liver, arterial, venous, lymphatic and excretory communicate with each other.

The bile assists in digestion, but the mode is entirely unknown. From our ignorance of the causes of disease, we often attribute pernicious qualities to the bile, that it, very probably, is far from possessing.

Secretion of Urine.

The secretion, to which we are now about to call the attention of the reader, differs in many respects from the preceding. The fluid which is the result of it, is much more abundant than that of any other gland, and instead of performing any further uses in the economy, it is destined to be expelled. We are informed of the necessity of doing this, by a peculiar sensation, which, like other instinctive phenomena of this kind, becomes very vivid and painful; if it be not satisfied promptly, its retention is accompanied by the most troublesome consequences. There are few of the organs of secretion so complicated as that of the urine. It is composed of the two *kidneys*, the *calices*, the *pelvis*, the *ureters*, the *urinary* bladder, and the urethra. The abdominal muscles, also concur in the action of these different parts; the kidneys alone secrete the urine, the others only serve the purposes of retaining, transporting, and expelling it.

The *kidneys* are small, in proportion to the quantity of fluid they secrete. They are generally surrounded with a large quantity of fat, and are situated, on the sides of the vertebral column, before the last of the false ribs, and the quadratus lumborum. Their parenchyma is generally composed of two substances; the exterior, which is very vascular, is called the cortical; the other part, called medullary or tubular, is arranged into a certain number of cones, the bases of which correspond to the surface of the organ, and the apices unite in a membranous cavity called the pelvis. These cones appear to be formed by a large number of small hollow fibres, which are excretory ducts of a particular kind, and are constantly filled with urine. There is no organ which receives so much blood, in proportion to its volume, as the kidney. The artery is short and large, and arises directly from the aorta; it communicates, very freely, with the veins and tubular substance, as may easily be shewn, by injections of the coarsest kind, which, when pushed into the renal artery, pass into the veins and pelvis, after having filled the cortical substance. Filaments of the great sympathetic, are the only nerves distributed to the kidney.

The calices, pelvis, and ureters, form together a canal, which passes from the kidney, where it embraces the papillæ, and terminates in the bladder. This last organ is an extensible and contractile sac, destined to receive the fluid secreted by the kidney, and which communicates externally, by a canal called the *urethra;* this is long in man, but short in the female. The posterior extremity of the urethra in man, is surrounded by the *prostate gland*, which has been considered, by some anatomists, a mass of mucous follicles. Two small glands placed before the anus, pour out a particular fluid into this canal. Two muscles, descend from the pubis towards the rectum, pass along the sides of that part of the bladder, which terminates in the urethra, approach each other posteriorly, and thus form an arch which embraces the neck of the bladder, and raise or depress it.

If we divide the pelvis of the kidney, in a living animal, we can perceive the urine oozing out slowly from the papillæ; this fluid is deposited in the cavity of the calices, afterwards in that of the pelvis, and gradually in the ureter, through which it at last penetrates, to the bladder, into which it continues constantly to trickle, as it is easy to perceive in persons affected by a deformity, called a *retroversion of the bladder*, in which the internal surface of this organ is exposed to view. A slight compression of the papillæ forces the urine out in a considerable quantity, but instead of being limpid, as it is naturally, it is thick and turbid. It appears therefore to be filtered, by the hollow fibres of the tubular substance. Neither the pelvis nor the ureter being contractile, it is probable that the force which determines its progress, is partly that by which it is poured into the pelvis, and partly the pressure of the abdominal muscles; to which may be added, when the body is erect, the weight of the fluid.* Under the influence of these causes, the urine is introduced into the bladder, and, by degrees, distends this organ; sometimes to a considerable extent, the extensibility of its different membranes, permitting this accumulation.†

* As it is proved, that the heart and the elasticity of the arteries, have a marked influence on the course of the blood in the capillaries and veins, may not these causes act upon the fluids in certain excretory ducts?

† Physiologists have often compared the introduction of the urine into the bladder, to that of a fluid into a cavity with resisting walls, by a narrow, vertical and inflexible canal; but the comparison is not exact. In the supposed canal, the fluid runs and presses continually the fluid contained in the vessel which receives it. The urine does not run in the ureter; it trickles, drop by drop, and in this respect its influence upon the distension of the bladder cannot be compared to that which is produced by the weight of a fluid. The abdominal pressure must have a great influence in the dilatation of the bladder by the urine. If the bladder, and ureters be equally pressed; this cause will be sufficient to introduce the urine into the bladder. Supposing the pressure to be equal in every part of the abdomen, if the surface of the pelvis of the kidney and ureters be superior to the bladder, the urine should enter easily into the last. But the abdominal pressure appears to be much weaker in the cavity of the pelvis, than in the abdomen, properly so called. It is thus easy to conceive how the urine passes

Why does the urine accumulate in the bladder, why does it not immediately pass out by the urethra, or flow back into the ureters? The answer, as respects the ureters, is very easy; these ducts pass for a considerable distance, through the substance of the walls of the bladder. In proportion, therefore, as the urine distends this organ, it flattens the ureters; closing them most exactly, when it is abundant. This effect takes place, as well in the living, as the dead body; a liquid, or even air, pushed with great force into the bladder, cannot be introduced into the ureters. It is owing, then, to a mechanism analogous to that of certain valves, that the urine does not return towards the kidney.

It is not so easy to explain the reason that the urine is not immediately poured into the *urethra;* many causes seem to concur in producing this effect. The walls of this canal, especially towards the bladder, tend continually to react upon themselves, and to efface its cavity; but this cause alone would be insufficient to resist a considerable effort of the urine to escape, when the bladder is distended. In the dead body, where the same disposition exists in the canal, the resistance is very weak, and does not prevent the fluid from passing out, however slightly the bladder may be compressed. The angle made by the urethra with the bladder, when it is much distended, may also act as an obstacle to the passage of the urine. But I believe the principal cause which prevents this effect, is the contraction of the *elevator muscles of the anus*, which, either from the disposition in their fibres to shorten themselves, or from their contraction under the direct influence of the brain, press the urethra from below, upwards, thus bringing its walls in contact, and closing its posterior orifice.

Excretion of the Urine.

When the urine is accumulated in certain quantities in the bladder, we feel a desire to expel it. The mechanism by which this is effected, deserves particular attention, as it has not been always rightly understood. If the urine be not constantly passing out, this is not owing to any want of contraction in the blad-

from the ureters into the bladder. However, the distension of the bladder by the urine has its limits. When it is carried to such an extent that the organ contains more than a pound of urine, the distention stops, and the ureters in their turn become dilated from their inferior, towards their superior part.

der, for this organ has always a tendency to react upon itself. But, by the influence of causes that we shall now point out, the internal orifice of the urethra resists this with a force, that the contraction of the bladder is incapable of overcoming. This condition of things is removed by the will; first, by adding to the contraction of the bladder, that of the abdominal muscles; second, by relaxing the elevator muscles of the anus, which close the urethra. When this resistance is once overcome, the contraction of the bladder is sufficient for the complete expulsion of the urine which it contains; but if the action of the abdominal muscles be added, the force and size of the stream is much increased. We can suddenly stop the flowing of the urine, by contracting the levatores ani muscles.

The contraction of the bladder is not voluntary; though by the action of the abdominal and levatores ani muscles, we can permit its contraction at pleasure. What urine remains in the urethra, after the bladder is emptied, is expelled by the contraction of the muscles, called the *acceleratores urinæ.*

Though the quantity of this fluid is very abundant, and though it contains many immediate principles not found in the blood, and which are, therefore, formed by some chemical action in the kidneys, the secretion of urine is very rapid. During health, the urine is of a yellow colour, more or less deep, its taste saltish, and a little acrid, and its odour peculiar. It is composed of water, mucus, probably derived from the mucous membrane of the urinary passages, of other animal substance, uric acid, phosphoric, acid, lactic acid, muriate of soda and ammonia, phosphate of soda and ammonia, lime, magnesia, sulphate of potash, lactate of ammonia and silex. The physical properties of the urine, are subject to great variations. If we make use of rhubarb or madder, it becomes of a deep yellow; if we respire air loaded with the vapours arising from turpentine, or if we take this drug internally, the urine assumes an odour like violets; every one knows the disagreeable odour of the urine, after eating asparagus.

Its chemical composition is equally variable. The more water we drink, the greater the proportion of water in the urine; and the reverse. The uric acid becomes abundant, when the diet is very generous, while the person exercises but little; but this acid diminishes, and may even be made to disappear entirely, by the continued and exclusive use of non-azotic aliments; such as sugar, gum, and butter, &c. Some salts, when introduced into the stomach even in small quantity, are found in a very short time in the urine. The extreme rapidity with which this is effected, has given rise to the belief, that there exists a direct communication from the stomach to the bladder; even at this time, there are many persons of this opinion. For a still longer time it has been suspected, that there was a duct passing from the stomach to the bladder; but no such part has ever been demonstrated. Some have thought, but without adducing any proof of the fact, that this took place through the cellular tissue, by the anastomoses of the lymphatic vessels.

Darwin having given to one of his friends a few grains of the nitrate of potash, collected the urine at the end of a few hours, and then bled him. The salt was found in the urine, but could not be recognised in the blood. Mr. Brande made a similar observation with the prussiate of potash; he concluded, that the circulation is not the only medium of communication between the stomach and bladder, but did not undertake to explain what this medium was. Sir Everard Home is likewise of the same opinion. I have made some experiments, with a wish to throw some light on this important question, and I have found; first, that when we inject the prussiate of potash into the veins, or into those parts where it will be rapidly absorbed, as the intestines or serous cavities, it soon passes into the bladder, where it may be recognised mixed with the urine. Second, if the quantity injected be very great, its existence in the blood may be demonstrated by reagents; but, if the quantity used by very small, it is impossible to detect its presence by any known method. Third, the same thing takes place, when we mix in a vessel the prussiate and blood. Fourth, we can detect the existence of this salt in all proportions in the urine. There is nothing very remarkable, therefore, in the fact, that Darwin and Brande could not find this substance in the blood, though its presence in the urine was distinctly perceived.

With respect to those organs which transport the fluids of the stomach and intestines into the circulating system, from what has been already said in speaking of the lacteal vessels and the absorption of the veins, it is evident, that the veins absorb the fluids directly, and transport them to the liver and heart. The route which the fluids pass through, therefore, to arrive at the kidneys, is much shorter than is generally supposed; that is, through the lymphatic vessels, mesenteric glands, and thoracic duct.

In explaining glandular secretion, physiologists have given a loose rein to their imaginations. The glands have been successively considered as sieves, filters and fermenting vats. Bordeu and, more recently, Bichat, have attributed to their molecules, a sensibility, and peculiar motion, by which they elect, from the blood which traverses them, the particles proper to enter into the composition of the fluids they are destined to secrete.* Some have given to them atmospheres, departments; others have supposed them susceptible of erection, sleep, &c. But notwithstanding the efforts of many very eminent men, it must be acknowledged, that we are at present entirely ignorant of what takes place in a gland when it acts. Chemical phenomena are, necessarily developed. Many secreted fluids are acid, while the blood is alkaline; many of them contain immediate principles, which do not exist in the blood, and which are formed in the glands; but the particular mode of these combinations is unknown.

But we will not confound among these hypotheses of the action of the glands, a very ingenious suggestion of Mr. Woolaston. This distinguished chemist being under an impression that electricity, even when very weak, might have a decided influence upon the secretions, had recourse to the following curious experiment. He took a tube of glass about two inches high, and about three quarters of an inch in diameter, and closed one extremity with a piece of bladder. He then poured into the tube a little water, with 1.240 part of its weight of muriat of soda, he then moistened the bladder, placed it upon a bit of silver, and bent a piece of zinc wire, so that one of its extremities touched the piece of metal, and the other penetrated into the tube to the depth of about one inch. At this moment the external face of the bladder indicated the presence of pure soda. There was,

* Bordeu acknowledges, that this is a mere metaphorical mode of expression. Vide Researches on the Glands.

therefore, from this very weak action of the electric fluid, a decomposition of the marine salt, and at the same moment, the soda separated from the acid and penetrated through the bladder. Mr. Woolaston thinks that it is not impossible that something analogous takes place in the secretions. It will be perceived, that before this idea can be fully admitted, many other proofs must be required.*

Many organs, such as the thyroid and thymus, the spleen and the capsulæ renales, have been called glands by anatomists. Professor Chaussier has substituted for this denomination, *glandiform-ganglions*. We are totally ignorant of the uses of those parts; as they are, in general, most voluminous in the fœtus; it is thought, that they perform some important function during this state; but there is no absolute proof of this. The works of physiologists contain a great number of hypotheses, constructed for the purpose of explaining their functions.

OF NUTRITION.

We know that the blood supplies the materials for all the secretions, internal and external; that its powers are preserved by general absorption, and by the chyle and drink. It remains for us now, to examine what takes place in the parenchyma of the organs and tissues during life; this is called nutrition. From the earliest periods of life to advanced old age, the body is constantly changing in weight and volume. The different organs and tissues present infinite varieties in consistence, colour, elasticity, and, frequently, chemical composition. The volume of organs augments when they are frequently in action; on the contrary, their dimensions diminish much, when they remain long in a state of repose. By the influence of one or other of these causes, their physical and chemical properties exhibit surprising variations; a great number of diseases produce, often in a very short time, very remarkable changes in the conformation and structure of a great number of organs. If we mix madder with the food of an animal, during fifteen or twenty days, the bones present a red tint, which disappears when it is omitted.

* For the secretion of the semen and milk, see Generation.

There exists, then in the very substance of the organs, an insensible motion of their particles, which produces all these modifications. It is this intestine motion, of the nature of which we are ignorant, to which we give the name of *nutrition*. This phenomenon, which the observing spirit of the ancients did not allow them to overlook, has been the object of many ingenious suppositions, that are admitted by some at this day. It is said, for example, that by means of nutrition, the whole body is renewed, so that at any given moment, it is not formed of a single particle that composed it at some former period. Limits have even been assigned to this total renovation. Some have fixed three years, others think it cannot be completed in less than seven; but there is nothing to justify these conjectures; on the contrary, some well established facts appear to do away this idea.

Every body knows that soldiers, sailors, and savages, are in the habit of colouring their skin with certain substances, which they introduce into the tissue of this membrane. The figures thus traced, preserve their form and colour during life, except under very peculiar circumstances. How does this phenomenon agree with this idea of renovation, which according to authors takes place in the skin?*

According to the suppositions of which we have now spoken, it is understood, in the metaphorical language at present used in physiology, that the particles of organs cannot serve but a certain time in their composition; and, being no longer suitable to compose the organs, they are then absorbed, and replaced by new molecules, arising from the aliment. It may be added, that the animal substances which compose our excretions, are the demolished organs, and that they are principally composed of particles, no longer capable of serving in the composition of the body, &c.

* The recent employment of the nitrate of silver, internally, in the treatment of epilepsy, has furnished a new phenomenon of this kind. After this remedy has been used for several months, the skin of many patients has become of a greyish blue colour, probably owing to this salt being deposited in the tissue of this membrane, where it is placed in immediate contact with the air. Several individuals have remained in this state for many years, without the colour being diminished. In others, it has by degrees diminished, and disappeared at the end of two or three years.

Instead of discussing this hypothesis, let us examine the few facts which are ascertained on the subject of nutrition. In observing the promptitude with which the organs change their chemical and physical properties by disease and age, it appears that nutrition is more or less rapid, according to their particular tissue. The glands, muscles, skin, &c. change their volume, colour, and consistence with great rapidity; the tendons, fibrous membranes, the bones and cartilages, appear to have a much slower nutrition, as their physical properties change but slowly in consequence of age or disease.

If we take into consideration the quantity of aliments consumed, in proportion to the weight of the body, it appears that the action of nutrition is much more rapid in infancy and youth, than in the adult or advanced age; it is accelerated by the action of the organs, and retarded by their remaining in a state of rest. Children and young persons consume more food than adults, and old persons; the last preserve their faculties with a very small quantity of aliment. All exertions of the body, render a more abundant and nutritious diet necessary; a state of perfect repose, on the contrary, will permit a prolonged abstinence.

The blood appears to contain the greater part of the principles necessary to the nutrition of the organs; the fibrine, the albumen, the fat, salts, &c. which enter into the composition of the tissues, are found in the blood. They appear to be deposited in their parenchyma, at the moment when the blood passes through them; the mode of this deposition is entirely unknown. There exists an evident connexion, between the activity of the nutrition of an organ, and the quantity of blood it receives. The tissues, the nutrition of which is rapid, have large arteries; when the action of an organ has determined an increased nutrition, the arteries and veins grow larger. There are many immediate principles entering into the composition of organs, which are not found in the blood, such are osmazome, cerebral matter, gelatine, &c. They are formed at the expense of the other principles in the parenchyma of the organs, by a chemical action, the mode of which is unknown.

Since the nature of the different tissues of the animal economy has been ascertained by chemical analysis, we know that they all contain a large portion of azote. Our aliments being, also, composed in part of this simple substance, it was probable that the azote of the organs was derived from them; but many respectable authors think, that it arises from respiration, and others, that it is entirely formed by the influence of life. Both these opinions are supported, particularly, by the example of herbivorous animals, which feed exclusively on substances not containing azote, or the history of certain nations, whose inhabitants live entirely on rice and maize; or that of negroes, who live for a long time upon sugar, and finally, on what is said of caravans, who in traversing the desert, have little other food for a long time than gum. If these facts prove, indeed, that men are capable of living for a long time without azotic aliments, it would seem necessary to acknowledge, that the azote of the organs has some other origin than the aliments. But in fact, nearly all the vegetables employed for the nutrition of man and animals, contain more or less azote. For example the raw sugar eaten by the negroes, is composed of it in a considerable proportion; with respect to those people who are said to live on rice and maize, it is well known that they add to this diet, milk and cheese; now cheese, of all the immediate nutritive principles, has the most azote.

It occurred to me, that we might acquire more exact notions on this subject, by submitting animals, for a sufficient period, to a particular diet, the chemical composition of which, should be determinate, and rigorously pursued. Dogs were very proper for these experiments, as, like man, they are nourished by vegetable and animal substances. Every one knows that a dog can live for a long time on bread alone; but, from this fact, nothing can be conclusively inferred relative to the production of azote in the animal economy; for the gluten contained in the bread, abounds in azote. To obtain a satisfactory result, it would be necessary to feed one of these animals with a substance considered nutritious, but which does not contain azote.

With this intention, I put a dog, about three years old, fat and healthy, upon a diet exclusively of pure refined sugar, with distilled water for drink; he had them both without any limit. For seven or eight days, he appeared to be very well; he was sprightly, ate with avidity, and drank as usual. He began to grow thin the second week, although his appetite was good, and he ate six or eight ounces of the sugar in twenty-four hours. His alvine excretions were neither frequent nor copious, and the urine was in sufficient abundance. The emaciation increased in the third week, the strength diminished, the animal lost its spirit, and its appetite became less. At this period, there occurred, first upon one eye and then upon the other, a small ulcer on the centre of the transparent cornea; it augmented rapidly, and at the end of a few days it was about a line in diameter, its depth increasing in the same ratio; the cornea became soon perforated, and the humours of the eye discharged. This singular phenomenon was accompanied with an abundant secretion of the glands about the eye-lids.

In the mean time, the emaciation continued to increase, and the strength to diminish, and, though the animal ate daily three or four ounces of sugar, its debility became so great, that it could neither chew nor swallow, of course every other motion was impractible. It expired on the thirty-second day of the experiment. I examined the body with every possible precaution; there was no fat to be found; the muscles were reduced more than five-sixths of their ordinary volume, the stomach and intestines were much diminished in size, and strongly contracted. The gall and urinary bladders were distended by the fluids peculiar to them. I requested M. Chevreul to examine them; he found them possessing nearly all the characters belonging to the urine and bile of herbivorous animals; that is, the urine, instead of being acid, like that of carnivorous animals, was sensibly alkaline, not exhibiting any trace of uric or phosphoric acid. The bile contained a considerable proportion of pycromel, a substance peculiar to the bile of the ox, and in general of all herbivorous animals. The excrements were also examined by M. Chevreul; they contained very little azote, though they ordinarily exhibit much of this substance.

Such a result deserved to be verified by new experiments; I was, therefore, induced to submit a second dog to the same regimen, namely, sugar and distilled water. The phenomena were similar to those just described, except that the eyes did not begin to ulcerate until the twenty-fifth day, and the animal died before the ulcer had penetrated into the cavity of the eye, as occurred in the dog that was the subject of the first experiment. In other respects, the same emaciation and debility, followed by death on the thirty-fourth day, occurred; and on opening the body, the same state of the muscles and abdominal viscera, especially the same characters in the excrements, bile and urine were discovered. A third experiment afforded exactly similar results; and I was therefore induced to conclude, that sugar alone is incapable of nourishing dogs.

It was interesting to determine, whether the defective nutritious qualities were peculiar to sugar, or whether they existed in common with other non-azotic substances, generally esteemed nourishing. I took two dogs, young and vigorous, but small in size; I gave them for food, very good olive oil and distilled water, as their constant diet. They appeared to be perfectly well for about fifteen days; after which they experienced a series of symptoms similar to those related, of the animals that were fed on sugar. No ulceration of the cornea, however took place, but they died on the thirty-sixth day of the experiment; they presented a similar state of the organs; and in the composition of the urine and bile, the same phenomena as in the preceding cases.

Gum is another substance which does not contain azote, but is generally considered nourishing; we might presume that it would act like sugar and oil, but it seemed desirable to determine this by direct experiment. With this view, I fed several dogs upon gum, and the phenomena I observed did not sensibly differ from those, of which I have already given an account. I have recently repeated the experiment upon a dog with butter, an animal substance destitute of azote. Like the animals in the preceding cases, he at first supported this diet very well; but at the end of fifteen days, he began to lose his flesh and strength. He died on the thirty-sixth day, although, until the thirty-second, I gave him this food as freely as he would eat it, and though he continued to eat until two days before his death. The right eye of this animal exhibited an ulcer of the cornea, similar to that mentioned to have taken place in the animals fed upon sugar. On opening the body, the same modifications of the bile and urine were noticed. Although the nature of the excretions of these animals, shewed that they had digested the substances which they had eaten, I was desirous of satisfying myself, more positively, on this point. For this purpose, after having fed several dogs upon oil, gum, or sugar, I opened them and found that these substances were reduced into a particular chyme, and that they afterwards furnished an abundant chyle. That which came from the oil was of a white, milky appearance; the chyle produced by the gum or sugar, was transparent, and more watery, than that of the oil. It is evident, therefore, that if these different substances do not nourish the body, it cannot be attributed to their not being digested.

These facts appear important in more than one respect; in the first place, they render it very probable, that the azote of the organs is primarily derived from the aliments; and they throw some light on the causes and treatment of the gout and gravel.*

A great number of tissues in the economy do not appear to undergo the process of nutrition, properly so called; for example, the epidermis, the nails, the hair, the teeth, the colouring matter of the skin, and perhaps the cartilages. These different parts are really secreted, either by particular organs, as the teeth and hair, or by parts which perform, at the same time, other functions, as the nails and epidermis. These parts seem to be formed to prevent the friction of foreign bodies, and are renewed proportionally; when completely removed they are reproduced. It is a singular fact, that they continue to grow for several days after death; we have had occasion to mention a similar phenomenon respecting the mucus. After these few observations on the principal phenomena of nutrition, it will be proper to examine a very important phenomenon, which appears to be intimately connected with nutrition, and respiration; I refer to the production of heat in the human body.

* Persons attacked with those diseases, are generally great eaters of meat, fish, milk, and other substances abounding in azote; gravel, urinary, and arthritic calculi are formed by uric acid, a principle that contains much azote. Perhaps by diminishing the proportion of azotic aliments, we may prevent these diseases.

OF ANIMAL HEAT.

A DEAD body, which does not change its state, when placed in the midst of other bodies, soon acquires the same temperature, in consequence of the tendency of caloric to arrive at an equilibrium. The human body acts differently; when surrounded by bodies warmer than itself, it preserves, during life, a lower temperature; when surrounded by bodies of a lower temperature than itself, its temperature remains more elevated. There is, then, in the animal economy, two distinct and different properties, the one producing heat and the other cold. Let us examine these two properties, and inquire, in the first place, how heat is produced. The principal, or rather the most evident cause, is respiration. Experiment demonstrates to us, in fact, that the blood becomes heated about one degree, in passing through the lungs; and as it is carried from the lungs to every part of the body, it carries every where warmth, and imparts it to the organs. We have already seen that the venous blood is colder than the arterial.

This development of heat in respiration, appears to arise, as we have already observed, from the formation of carbonic acid, whether this takes place directly in the lungs, or in the parenchyma of the organs. The very beautiful experiments of Lavoisier and Laplace, lead to this conclusion; they placed in a calorimoter, animals, and compared the quantity of heat produced, with the quantity of carbonic acid formed in a given time; within a very small proportion, the heat produced was such as would necessarily be evolved, from the quantity of carbonic acid formed.

The experiments of Messrs. Brodie, Thillage, and Legallois, also prove, that if the respiration of an animal be obstructed, either by placing it in a fatiguing posture, or in making it respire artificially, its temperature is diminished, and the quantity of carbonic acid formed, less. In those diseases where the respiration is accelerated, the animal heat is augmented, except under particular circumstances. Respiration is, therefore, a centre from which the animal heat is developed. In considering this as the source of heat in the animal body, we see that the caloric must be distributed to the different parts of the body, in an unequal manner. Those parts which are most distant from the heart, or receive less blood, or which cool the easiest, must be generally colder than those which present a contrary arrangement. This in fact, is found to be actually the case. The limbs are colder than the trunk; they are often found at 88° or 90° Far. and even less, while the cavity of the thorax approaches 104°. But the extremities have a considerable extent of surface, in proportion to their mass, they are more distant from the heart, and receive less blood than most of the organs of the trunk. From the extent of their surface, and their distance from the heart, it is probable, that the feet and hands would have a still lower temperature, than what is observed generally, if these parts did not receive a large quantity of blood. The same disposition exists in all the external organs, the surfaces of which are very extensive, the nose, cartilages of the ears, &c. their temperature is higher than would be anticipated, from their surface and distance from the heart.

But notwithstanding this foresight of nature, the parts with large surfaces, lose their caloric more easily, and are not only habitually colder than the rest, but frequently experience considerable chills. The temperature of the hands and feet is frequently reduced in winter, much below that of the neighbouring parts; this is the reason why we expose them more freely to the fire. Among the means we instinctively use, to prevent or remove the cold, are running, walking, leaping, &c. which accelerate the circulation; and blows and pressures upon the skin, which draw into the tissue of this membrane a large quantity of blood. Another method, equally efficacious, is diminishing the surface in contact with the body which conveys away the caloric, as flexion of the different extremities upon each other, or placing them in contact with the trunk. Children and weak persons, often adopt this when they lie down,* for this, among other reasons, it is improper to dress children in swaddling clothes, when they are to lie down in the cold. Our clothes preserve the heat; for the materials which compose them, being bad conductors of heat, do not allow it to escape from the body.

* See Memoir of Mr. Bies, in the Journal de Medecine, Annee, 1817.

From what has been said, it appears, that the combination of the oxygen of the air with the carbon of the blood, is sufficient to explain most of the phenomena which occur in the production of animal heat, but there are some, which, if real, cannot be explained in this way. It has been observed, by persons worthy of belief, that, in certain local diseases, the temperature of the part diseased, becomes greater than that of blood, taken from the left auricle, by several degrees. If it be so, the continual return of the arterial blood will not be sufficient to explain this increase of heat. This second source of heat, must be connected with the nutritive phenomena, which take place in the diseased part. There is nothing forced in this supposition, for chemical combinations generally give rise to changes of temperature, and we cannot doubt that, both in secretion and nutrition, combinations of this kind take place in the textures of the organs.

By means of these two sources of heat, life may be preserved, though the body be exposed to a very low temperature; as that of winter in polar regions, where the thermometer often falls to 108° or 109° below zero. In general, we support with difficulty such excessive cold, and it often happens, that those parts which are cooled the soonest, freeze and mortify; this was experienced by many of the soldiers in the Russian war. However, as we are capable of resisting, easily, a low temperature, it is evident we possess the power of evolving heat to a great degree.

That of producing cold, or in more precise terms, of resisting heat, is more limited. In tropical countries, it has often happened, that men have died suddenly, apparently from the heat, when the themometer has risen to 120° Far. But our power of resisting heat, is by no means limited to this. Messrs. Banks, Blagden and Fordyce exposed themselves to a temperature of nearly 257°, and found that their bodies preserved nearly its ordinary temperature. The more recent experiments of Berger and Delaroche have shown, that the heat of the body could be raised, by these means, several degrees. It is not necessary, even for this effect, that the surrounding temperature should be very high. Having placed themselves in a stove, at 119°, their temperature was raised about three degrees. M. Delaroche, having remained sixteen minutes in a dry stove, at 176°, found an increase of 4° in his person.

Franklin, to whom the physical and moral sciences are indebted for many important discoveries and ingenious observations, was the first who explained how the body resists excessive heat. He shewed, that this was the effect of the co-operation of the pulmonary and cutaneous transpiration, and that, in this respect, the bodies of animals resemble porous vases, called *alcarrazas*. These vases, used in warm countries, allow the water they contain, to ooze out, and thus to keep their surfaces constantly wet, from which arises a rapid evaporation, which cools the fluid they contain. To confirm this important fact, M. Delaroche placed animals in a warm atmosphere, saturated with humidity, so that evaporation could not take place. These animals could not support but a moderate degree of heat, and became warmed, as if they had no means of cooling themselves. It is thus placed beyond doubt, that cutaneous and pulmonary evaporation, are the causes by which man and animals resist a great degree of heat. This explanation is still [illegible] confirmed, by the great loss of weight that the body undergoes, when it is exposed to a high temperature.

From the facts which have thus been exposed, it is evident, that the authors who have represented animal heat as fixed, are very far from the truth. To judge correctly, it is necessary to take into consideration the temperature and humidity of the surrounding atmosphere. It is also necessary to consider the temperature of the different parts, and not to judge of one by that of another. Few observations have been made on the temperature peculiar to the human body; Messrs. Edwards and Gentil, have most recently investigated the subject. These authors have remarked, that the place most favourable to judge of the heat of the body, is the arm-pit. They have remarked a difference, of nearly a degree, between the heat of a young man and that of a young girl; the hand of the last presented a temperature somewhat less than 98°, that of the young man was nearly 99°. The same authors have observed remarkable differences in the heat of persons of different temperaments. There are diurnal variations; the temperature varies two or three degrees from morning to evening. In general this subject requires further investigation.

OF GENERATION.

The functions of relation, and nutrition are necessary to the existence of the individual; but, like all other animals, man is called on to exercise another very important function, the reproduction of his species. In its object, generation differs, very essentially, from the functions of relation and nutrition; but it differs still more essentially in this, that the organs which co-operate in it, do not exist in the same individual; this constitutes the principal difference between the sexes.

Apparatus of Generation.

It is composed of the organs proper to man, and those peculiar to the female.

Organs of Generation in Man.

These organs are, the *testicles*, *vesiculæ seminales*, *prostate*, and *penis*.

Testicles.—These are two in number; the cases related by authors, who assert that they have seen three and even four, are very doubtful. Their form is ovoid and their size inconsiderable; their parenchyma consists of an infinite number of small vessels folded and rolled upon themselves, called *tubuli seminiferi*, and are directed towards a point of the surface, called the *head of the epididymis*. Here they meet and anastomose, at the same time diminishing in number, and finish by forming a convoluted canal, called the *epididymis*. It soon leaves the organ; when it receives the name of *vas deferens*. It then rises up towards the inguinal ring, plunges into the pelvis, and arrives at last at the inferior and anterior part of the bladder; there it communicates with the vesiculæ seminales, and the *prostate* portion of the urethra.

The parenchyma of the testicle is enveloped by a strong fibrous membrane; it is also covered, first, by a serous membrane, called the *tunica vaginalis testis;* which in the fœtus makes a part of the peritoneum; second, by a muscular membrane, which is capable of elevating the testicle, and applying it against the ring; third, by the *dartos*, a layer of loose cellular tissue, which appears to be contractile; fourth, by a rugous skin of a dark colour, which forms the scrotum.

The arterial blood arrives at the testicle by a small artery, derived from the aorta, near the emulgent arteries. The veins of this organ are large, tortuous, and numerous; have frequent anastomoses, and have together received the name *pampiniform bodies.* Although the sensibility of the testicle is very great, it does not appear that any nerve can be traced to it either from the brain or ganglions.

Vesiculæ seminales.—This name has been given to two small cellular bodies, below the *basfond* of the bladder, and which appear to be destined to contain the fluid secreted by the testicle. Their walls are thin, covered internally by a mucous membrane, and externally by a fibrous coat; we do not know whether the intermediate membrane is, or is not contractile. The anterior extremity of these small vesicles, communicate with the vas deferens and urethra, by a very short and narrow canal, called the *ejaculator.*

Penis.—This is the only part of the male organs of generation, which remains to be described. It is formed by the *cavernous bodies*, the *spongy portion of the urethra,* and the *glans penis.* The cavernous bodies principally determine the form and dimensions of the penis. They commence on the internal part of the *rami ischii*, approach each other, and soon unite to form the body of the penis. They are separated from each other by a fibrous partition, pierced with several openings; their external membrane is fibrous, thick, hard, and very strong. Their interior consists of laminæ, crossing each other in various directions, which together form a sort of sponge, in which the blood is extravasated. The urethra and glans, which are also essential parts of the penis, have a similar structure, but are not surrounded by a fibrous membrane. Six arteries are distributed to the penis; this part also receives many nervous filaments, arising from the nerves of the sacrum.

The genital organs in man really consist of but one apparatus of glandular secretion, of which the testicles are the glands, the vesiculæ seminales the reservoir, and the vas deferens and urethra the excretory duct. This secretion is indispensable for generation. We give the name of *semen* to the fluid secreted by the testicles. The small volume of these glands, the number and tenuity of the spermatic ducts, the small quantity of blood carried by the spermatic arteries, and the length and extreme narrowness of the vas deferens, render it probable, that the quantity secreted is very small; and that it is propelled towards the vesiculæ seminales very slowly. It is probable, also, that the secretion is constant, but is increased by venereal excitement, the use of certain aliment, and the frequent indulgence of the venereal appetite. It is extremely difficult to explain, how the semen is made to traverse the tubuli seminiferi, epidydimis, and vas deferens. Perhaps it may be the effect of capillary attractraction; an idea which appears to receive some support from the small size of these parts, and thickness and strength of their walls. It is somewhat easier to understand, how the semen having arrived at the extremity of the vas deferens, can penetrate into the vesiculæ seminales. The ejaculatory ducts embraced, together with the neck of the bladder, by the *levatores ani* muscles, will resist at first the fluid, which will find a more ready access to the vesiculæ seminales.

The semen, as it passes from the testicles, has never been analysed; the fluid which has been examined under this name, is formed by the semen, the fluid secreted by the mucus membrane of the vesiculæ seminales, the prostate, and perhaps the glands of Cowper. At the moment when this fluid passes from the urethra, it is composed of two substances, the one fluid, and the other thick and nearly opaque. When left to themselves, these substances mix, and the mass liquefies in a few minutes. The odour of the semen is strong and peculiar; its taste saltish, and even a little acrid. Professor Vauquelin, who analysed it, found it composed of 900 parts of water, 60 of animal mucilage, 10 of soda, 30 of phosphate of lime. When examined by a microscope, there can be distinguished a multitude of small animalculæ, which appear to have a rounded head, and a long tail. These animalculæ move with a certain degree of rapidity; they appear to avoid the light, and to delight in the shade.

The secretion of the semen commences at the age of puberty; before this period, the testicles secrete a viscid transparent fluid, which has never been analysed, but which, to judge from appearance, differs essentially from semen. The revolution which the whole economy undergoes at this period, such as the tone of the voice, the development of hairs, the increase of the muscles and bones, &c. are intimately connected with the existence of the testicles, and the secretion of this fluid; indeed, the removal of these organs, previous to this period, prevents this development from taking place. Eunuchs preserve the same form as in childhood; their larynx does not increase, their chin is not covered with hair, and their disposition is generally timid; and finally, their physical and moral character very nearly resembles that of females. Nevertheless, many of them take delight in venereal intercourse, and give themselves up with ardour to a connexion, which must always be unfruitful. In a state of health, before an emission of semen takes place, the spongy tissue of the penis becomes warm, hardened and distended in every direction; in a word, in a state of *erection*. In this state, every thing shows, that the blood has been thrown into the penis, in large quantity; its arteries are enlarged, and beat with more force; its veins are swelled, and its temperature sensibly augmented. These different phenomena are evidently under the influence of the nervous system.

Different explanations have been given of erection. It has been referred to the compression of the pubic veins by the muscles of the penis; and to the constriction of the veins by nervous influence, &c. But as erection is an action purely vital, can it be explained? It may be produced by many and very different causes, such as mechanical excitement, venereal desires, the fulness of the vesiculæ seminales, the use of certain aliments, some medicines, and even certain poisons. It is also excited by several diseases, flagellation, &c. But of all these causes, the imagination is by far the most prompt. One of the most remarkable phenomena which attend erection, is, undoubtedly, the great rapidity with which it is reproduced, or ceases, in certain cases. Generally, erection is attended with oozing of a viscid transparent fluid, said to come from the prostate.

The circumstances which lead to the excretion of the semen and the sensation which accompanies it, are sufficiently well known; but the mechanism of its evacuation is much less understood. Are the vesiculæ seminales emptied entirely, or in part, at the moment of emission? Is it their middle tunic which contracts itself, or are they all compressed by other forces? Do the muscular fasciculi which pass from the orifice of the ureters to the crest of the urethra concur in it?* Are the levatores ani relaxed at this instant? Is it the contact of the semen with the membranous or spongy parts which excites the sensation which accompanies its expulsion? &c. &c. We cannot give any positive answers to these questions.

Female Organs of Generation.

They are the *ovaria*, *fallopian tubes*, *uterus* and *vagina;* at least, these are the essential organs.

Ovaria.—From the time of Stenon, the term ovaria has been applied to two small bodies, situated in the cavity of the pelvis, on each side of the uterus. Each ovarium is formed by an external fibrous membrane, and the interior by a peculiar cellular tissue; in the midst of which are fifteen, or twenty vesicles, of which some are larger than others, and correspond, by one of their sides, to the external membrane, which is thinner in that part. These vesicles appear to contain the rudiments of the germ, and to bear the same relation to women, that the eggs do to birds, reptiles and fishes. They are formed by two membranous envelops, and by a fluid which runs into a mass, and becomes hardened like albumen. When the ovaria are not developed, as sometimes happens in some individuals, it exerts an influence upon the ecomomy, which to be sure, is not similar but analogous to emasculation upon the male. Sterile women, for this reason, have often a form resembling men; with hair upon the chin, and about the mouth, and with a disposition and character like that of men. In such persons, the voice is often grave and sonorous, and the *clitoris* larger than natural. In this kind of imperfect woman (called a *Virago*,) is often found inclinations.

* See Charles Bell.

in themselves immoral, and which are generally, peculiar to man; which are interesting in a physiological point of view.

Fallopian Tubes.—These are two narrow canals, the one on the right, and the other on the left side of the uterus, which are media of communication between the internal part of the uterus and ovaria. Their external extremity is uneven and ragged; they are narrow, through the whole of their extent. Their tissue, especially towards the uterus, is very analogous to the vas deferens.

Uterus.—In the cavity of the pelvis, between the bladder and rectum, is found the uterus; it is pyriform, and small, in the ordinary state, but undergoes a surprising enlargement during pregnancy. We may divide it into *body* and *neck;* the last is embraced by the vagina; it has three orifices, two at the fundus of the uterus, communicating with the fallopian tubes, and one below, with the vagina. The tissue of the uterus is peculiar; there is nothing analogous to it in the animal economy, except some slight resemblance in the heart. Its structure is more easily studied in an advanced state of pregnancy, than in the ordinary condition. There are two prolongations of this tissue, sent to the inguinal rings, under the name of round ligaments; which spread themselves at the sides of the labia. A great part of the surface of the uterus is covered by the peritoneum, which forms many remarkable folds about the organ. The internal surface is covered by a mucous membrane; when we examine this surface with a magnifying glass of considerable power, we can perceive a multitude of small openings; of which some, less numerous but larger, belong to the veins of the organ, and others more numerous, appear to belong to the capillary arteries. The arteries of the uterus are flexuous and large, in proportion to its volume; the veins are likewise numerous and large. They form in the substance of the tissue, what has been improperly called by anatomists, *uterine sinuses;* the nerves are less numerous, and come from the hypogastric plexus.

Vagina.—The cavity of the uterus communicates externally with the vagina, a membranous canal placed nearly vertically in the cavity of the pelvis. It is from six to seven inches long, and its size various, depending upon the circumstance of the individual having had children. Its internal surface, especially at the lower part, has numerous transverse folds which allow the vagina to become stretched in pregnancy. At the inferior part of the vagina is the *hymen*, a delicate membrane, which nearly closes up the tube. The tissue of the vagina is composed of greyish fibres, crossing each other in various directions, somewhat analogous to those of the uterus. Below it is surrounded by numerous veins, which resemble the tissue of the cavernous bodies of the penis, and which form a *retiform-plexus*. It is supposed that this part of the vagina is susceptible of erection. All the internal surface of this organ is covered with a membrane containing many mucous and sebaceous follicles.

The external female organs are the *labia*, and *nymphæ*, folds in the skin, which are destined to become effaced during parturition, and the *clitoris*, which is a kind of small, imperfect penis, composed of two cavernous bodies, and of a sort of *glans*, covered with a *prepuce*. It is endued with great sensibility, and undergoes an erection similar to that of the penis.

Of Menstruation.

In most women, an aptitude for generation is indicated, by a periodical, sanguineous discharge, which takes place from the internal surface of the uterus, and is a true sanguineous exhalation. It is called *menstruation*, because it returns regularly at the end of a month. There are, however, some women in whom this discharge recurs at the end of every fifteen days, others once in two months, others again in whom it has no fixed period, and some few cases in which it never appears. The approach of this discharge is indicated by particular signs, such as a sense of weight in the loins, lassitude in the limbs, and pricking and pain in the nipples. Its first appearance is sometimes marked by serious accidents, at others, the discharge suddenly takes place, without any previous indication.

The duration of the discharge, its mode, the quantity of blood exhaled, its colour and consistence, are equally variable. With some women, the quantity of menstrual blood is considerable, sometimes to the extent of several pounds. When menstruation continues for eight or ten days, the discharge acquires all the qualities of arterial blood. In some individuals, only a few drops of blood are discharged, which is frequently watery and destitute of fibrine, in others it has all the characters of venous blood; the evacuation continues hardly a day, or stops and returns again. During menstruation, the susceptibility of females is much increased; the least noise frightens, a slight contradiction affects them and they are particularly irascible.

The regularity, or irregularity of the return of the *courses*, the nature and quantity of the blood evacuated, and the duration of the evacuation are intimately connected with the health of the individual; all deserve the particular attention of the physician. It has been shewn, by the dissection of women who have died during menstruation, that the blood escaped from the internal surface of the uterus, the vessels of which were found red, and filled with blood, which readily ran into the cavity, by slight pressure. Although the menstrual discharge takes place from the uterus, yet this is not always the case; many instances have been known where this evacuation occurred in the mucous membrane of the large intestines, stomach, lungs, and even the eye. Different parts of the skin have also been known to discharge blood periodically; thus it has been known to issue monthly, from one or more of the fingers, the cheek, the skin of the abdomen, &c.

Some distinguished authors, in their anxiety to find the immediate cause of menstruation, have attributed it to the influence of the moon, to the vertical position of the body, and to a generous diet. The period at which menstruation first takes place, in this climate, is towards the thirteenth or fourteenth year; it is earlier in warm, and later in cold climates. In equatorial regions, girls often arrive at puberty by the age of seven or eight years. Towards the age of fifty, but later in the northerly, and earlier in warm climates, menstruation ceases; and with it finishes the aptitude for generation. This period is called critical, and is often marked by the development of alarming diseases. What we have said of menstruation, is liable to many exceptions. Young girls have been often known to conceive, before menstruation has taken place; old women, in whom the courses had ceased at the ordinary period, have had them re-appear at the age of sixty or seventy, and have become mothers; lastly, women in whom menstruation has never been observed, have nevertheless become impregnated.

Copulation and Fecundation.

We have already remarked, that our individual existence is protected by certain instinctive sentiments. A sentiment of the same nature, but much more vivid and imperious because its end is more important, secures the preservation of the species, by inducing the sexes to approach each other, for the purpose of coition. The part performed by man, in the act of re-production, consists in depositing in the vagina, as near as possible to the os uteri, the semen. The part performed by the female is more obscure; a great number perceive, at this moment, the most vivid sensation of pleasure, while others appear insensible, and some even experience pain and disgust. Some discharge a large quantity of mucus, at the instant when the pleasure is most exquisite, while in the greater number of females, nothing of the kind is observed. In all these respects, there are not, perhaps, any two who resemble each other. These different phenomena take place in common copulations; i. e. those which are not followed by fecundation.

We will now inquire what takes place in fecundation. According to the latest physiologists, the uterus absorbs the semen, and directs it to the ovaria, through the fallopian tubes, the ragged extremities of which embrace closely this organ.* The contact of the semen, causes the rupture of one of these vesicles, and the fluid which passes out, or the vesicle itself, is carried into the uterus, where the embryo becomes developed. However satisfactory this explanation may appear, we must take care how we too readily admit it; for it is purely hypothetical, and contrary even to the experiments of the most careful observers. In the numerous experiments made upon animals, by Harvey, De Graaf, Valisnieri, &c. the semen could never be detected in the cavity of the uterus; much less in the fallopian tubes and ovaria. It is the same with the motion, by which the fallopian tubes embraces the ovaria; it has never been shewn by experiment. If we admit that the semen penetrates into the uterus, at the moment of coition, which is not impossible though it has never been observed, it will be then difficult to comprehend, how the fluid can

* I pass over the various hypotheses, both of the ancients and moderns, on generation. Why should the mind of the medical student be overloaded by these brilliant reveries, which have inconceivably retarded the progress of science?

pass through the fallopian tubes to the ovaria. The uterus, when empty, is not contractile; the uterine orifices of the tubes are extremely small, and have no sensible motion.

From the difficulty of conceiving how the semen could be transported to the ovaria, some authors have imagined, that it was not this substance that was carried to the ovaria, but only the vapour exhaled from it, which they called the *aura seminalis.* Others have thought, that the semen was absorbed from the vagina, passed into the venous system, and arrived at the ovaria by the arteries.* The phenomena which accompany fecundation in women, then, are but little understood; an equal obscurity rests on the fecundation of the females of other mammiferous animals. With these, however, it will be much easier to conceive of the passage of the semen to the ovaria, inasmuch as the uterus and fallopian tubes are capable of a peristaltic motion, similar to that of the intestines. Fecundation in fishes, reptiles, and birds, is effected by contact of the semen with the ovum; it may be presumed, that nature employs the same mode with the mammalia. We may consider it, therefore, as highly probable, that the semen passes, either at the moment of coition, or sometime afterwards, to the ovarium, where it performs its specific action upon the vesicle, which is afterwards to be developed.

But even if it be acknowledged, that the semen finds its way to the vesicle of the ovarium, it still remains to be shewn, how its contact animates the germ. Now this is a phenomenon, of which it is impossible that our senses should take cognizance. It is one of those mysteries which at present are, and will probably always remain inexplicable.† But we have the experiments of Spallanzani on this subject, which have done as much towards removing the difficulty, as perhaps can ever be effected. This illustrious naturalist has proved, by a great number of experiments; first, that three grains of semen dissolved in two pounds of water, still preserved its fecundating power. Second,

* If there was any truth in this idea, a female might be fecundated, by injecting the semen into the veins. This would be a curious experiment to try.

† The same obscurity surrounds this, as we find in the physical and moral resemblance observed between parents and children, the transmission of diseases, the sex of the new individual, &c.

that spermatic animalculæ, are not necessary to fecundation, as several authors, particularly Buffon, supposed. Third, that the seminal vapour has no fecundating property. Fourth, that a bitch may be fecundated by injecting semen into the vagina with a syringe, &c. &c.

We must consider as conjectural, what is said by authors of the general signs of fecundation. At the moment of conception, it is said, that the woman experiences a universal thrilling sensation, accompanied with a feeling of extreme pleasure, which continues for some time. The countenance becomes altered, the eyes lose their brilliancy, the pupil is dilated, and the face pale, &c. Without doubt, fecundation is often accompanied by these signs; but how many mothers are there, who have never experienced them; and who have arrived at the third month of pregnancy without suspecting their situation? Our ideas of the changes which take place in the ovaria after fecundation, are more exact. The most accurate observers have described a body of a yellowish colour, which is developed in the ovaria of fecundated females, which is at first rather large, but diminishes in size as pregnancy advances. But this phenomenon belongs to the history of gestation, which we are now about to investigate.

Of Pregnancy.

The period which elapses between fecundation and parturition, is called *pregnancy* or *gestation;* it is generally nine months, or two hundred and seventy days. All this time is required for the evolution of the organs of the new individual. To form precise notions of pregnancy, it is necessary to study successively the phenomena which take place in the ovaria, after fecundation, those of the fallopian tubes, of the uterus and adjacent parts, those of the economy generally, and, finally, those which are peculiar to the fœtus.

Ovaria.—Notwithstanding the numerous observations of anatomists and physiologists, on the changes which take place in the ovaria after fecundation, we have still much to learn on this subject. The difficulty consists in knowing, what is detached from the ovarium to pass into the uterus. Some assert, that they have seen a small vesicle detached from the ovarium, and pass into the fallopian tube; while others maintain, that nothing of the kind has ever been observed. I am now about to state the result of my own observations on this point. Twenty-four or thirty hours after a productive coition, those vesicles of the ovarium, which are the most developed, augment sensibly in volume. The tissue of the ovarium which surrounds them, becomes more consistent, and changed to a greyish yellow colour. In this state, the tissue of the ovarium takes the name of *corpus luteum*, yellow body. The vesicle continues to grow larger, until the second, third, or fourth day; and the corpus luteum grows in the same proportion; it contains a whitish opaque fluid, similar to milk in appearance. After this, the vesicle ruptures the external tunic of the ovarium, and passes to its surface, where it adheres by one of its sides. I have seen, in bitches, vesicles thus pass out from the ovarium, which had attained the volume of an ordinary hazel nut. In this state, they present no appearance internally, that can be considered a germ; their surface is smooth, and the fluid they contain does not run into a mass, as before fecundation.

After the escape of the vesicle, the corpus luteum remains in the ovarium, it presents in its centre a cavity which is large in proportion as it is near the period of conception; but in time it becomes diminished, like the corpus luteum itself. This diminution however, is very slow, and the ovaria always contain those of the preceding generation, which has frequently deceived observers. Thus the first effects of fecundation take place in the ovaria, and consist in the development of one or more vesicles, and as many corpora lutea. Sometimes the vesicles are found filled with blood; they appear to have been too strongly affected by the semen. It appears also, that, in certain cases, the vesicle of one or more of the corpora lutea become ruptured, before their entire development; for it is not rare to find more corpora lutea in the ovarium, than vesicles at its surface.

Action of the Fallopian Tubes.

Among the vesicles on the surface of the ovarium, there is ordinarily one which adheres to the open and mucous mouth of one of these tubes, the tissue of which is softened and gorged with blood, and exhibits a peristaltic motion. I have never directly detected the vesicle in the tube; but I have often seen the vesicle after it has descended towards the inferior part of the horn of the uterus, while another had contracted adhesions with the extremity of the tube. At this moment, the body of the tube was enlarged to nearly half an inch in diameter; it, of consequence, was sufficiently large to allow the vesicle to pass.

The period at which the vesicle traverses the tube, appears to vary, in different kinds of animals. In hares it appears to take place on the third or fourth day; in dogs the sixth or eighth. It is probable that it is still later in women; and that it does not take place until the twelfth. Dr. Maygrier assured me, that he had seen the product of fecundation thrown off by an abortion, of the twelfth day; it was a small vesicle, slightly shaggy on its surface, and filled with a transparent fluid. The vascular appendices, in which the tubes terminate in the human subject, are probably intended to contract adhesions with the vesicle, after it is detached from the ovarium; and to pour upon it a fluid that favours its development. After the vesicle has passed, the tube contracts and resumes its ordinary size. Having arrived at the uterus, the ovum unites itself, intimately, with the internal surface of this organ; it there receives the materials necessary to its growth, and acquires a considerable volume. The uterus accommodates itself to this change of form, and volume, &c.

Alteration of the Uterus in Gestation.

During the three first months of pregnancy, the development of the uterus is inconsiderable, and is made in the cavity of the pelvis; but in the fourth, it increases more rapidly, becoming too large to be contained in the pelvis, and rises into the hypogastric region. The organ continues to increase during the fifth, sixth, seventh, and eighth months; it occupies, gradually, a larger space in the abdomen, compressing and displacing the neighbouring organs, crowding them into the hypochondriac and iliac regions. At the end of the eighth month, it fills itself, the hypogastric and umbilical regions, and its fundus approaches the epigastric. After this the fundus sinks, and approaches the umbilicus. The neck of the uterus undergoes but little change in the seven first months of gestation; the viscus preserves, during this time, a conoid form. After this, the length of the neck is diminished, and at last becomes nearly effaced, and the uterus assumes an ovoid form; its volume, according to Haller, is nearly twelve times larger than when empty.

It is impossible that the uterus should become altered so remarkably in its form, volume and situation, without its relations to the neighbouring parts being essentially altered. In fact, the peritoneal coat, which forms the broad ligaments, is stretched, and the vagina elongated. The ovaria, retained by their arteries and veins, cannot rise with the fundus of the uterus; they are therefore applied to its side, together with the fallopian tubes. The round ligaments suffer its elevation as far as their length will permit; afterwards they offer some resistance to it, which tends to carry the fundus of the uterus forward, which must have a favourable effect on the abdominal circulation, by diminishing the pressure on the large vessels. The abdominal walls undergo a considerable extension; hence the rugous appearance upon the abdomen of women who have borne children.

In proportion as the uterus developes itself, its tissue loses its consistence; it assumes a deep red colour, and a spongy texture; its structure becomes more distinctly fibrous. We see, externally, longitudinal fibres passing from the fundus towards the neck, which are intersected at right angles by circular fibres. Beneath this tunic, the tissue of the uterus presents an inexplicable interlacement of fibres, in which no regular arrangement can be discovered. In this state, the organ appears to be endowed with a peculiar contractility, which, in animals, has a great analogy with the peristaltic motion of the intestines. Its internal surface, soon after fecundation, presents an albuminous coat, adhering strongly to it. This coat increases with the organ, in the early periods of pregnancy, but afterwards disappears, in a great measure. Dr. William Hunter,* who first described it carefully, called it the *membrana decidua.* It appears destined to favour the adhesion of the ovum, to the internal surface of the uterus.

These changes in the volume and structure of the uterus, necessarily modify its circulation. Its arteries undergo a considerable dilatation, the veins become enlarged, and form in the parenchyma of the organ what has been, improperly, called *uterine sinuses;* the lymphatic vessels also become very volumi-

* See his magnificent work, *De Utero Gravido.*

nous. It must be evident, that the quantity of blood which traverses the uterus in a given time, is proportioned to the changes it has undergone, and the new functions it is called upon to perform.

General Phenomena of Pregnancy.

While all these phenomena occur in the uterus, important modifications take place in the functions of the mother, and commence often immediately after fecundation. Menstruation does not reappear, the mammæ swell, and, if in a state of lactation, the milk becomes serous, and is frequently injurious to the infant. The eye-lids are swelled and of a blueish colour, and the countenance altered; the cutaneous transpiration assumes a peculiar odour; a general paleness, with a diminished or capricious appetite, are also often observed; sometimes continual nausea, with violent pain of the head, followed by distressing vomiting, occurs. The abdomen is often affected with an extreme sensibility and at first becomes flattened; some females lose their sleep, and are unable to leave a recumbent posture, without experiencing a sense of extreme fatigue; on the other hand, persons of a delicate constitution, and valetudinarians, often, have their health very much improved; alarming diseases are sometimes arrested in the midst of their course, and do not again resume it, until after parturition.

In general, the intellectual faculties of pregnant females are weakened, and they are affected, to an unusual degree, by the most trifling events; hence the necessity of those kindnesses, and attentions, which this peculiar situation demands. To these different symptoms, which it is impossible to explain, are added phenomena, evidently arising from an augmentation of volume in the uterus; such as cramps in the limbs, swelling of the superficial veins of the thighs and legs, and a sensation of numbness or pricking, arising from an obstruction in the circulation. In the later period of pregnancy, the bladder and rectum being strongly compressed, the desire of passing urine and going to stool are frequent. We shall not add to these phenomena, the existence of which is certain, suppositions destitute of proof; for example, that fractures in pregnant women are attended with more difficulty than in other women; the contrary of which is shewn by experience.

Development of the Ovum in the Uterus.

At first the ovum is loose in the uterus; its volume is nearly as small as when it left the ovarium; but, in the course of the second month its dimensions increase and it is covered by long filaments, of about a line in length, which ramify in the manner of sanguineous vessels, running into the membrana decidua, In the third month, we perceive them only on one side of the ovum, those on the other having nearly disappeared; but those which remain have acquired an increased size and consistence, and are implanted more deeply in the decidua, and at last constitute the *placenta;* over the remainder of its surface, the ovum presents a soft, shaggy coat, called the *decidua reflexa.* The ovum continues to increase and develope itself, until the termination of pregnancy, when its volume equals that of the inside of the uterus; but its structure has experienced changes which we are now about to examine.

At first, its two membranes are thick and strong. The external is called the chorion, and the internal the amnios. The fluid contained in the last, augments in proportion to the volume of the ovum; according to M. Vauquelin, it exhibits, at the same time, acid and alkaline properties. It is formed of water, albumen, muriate of soda, and phosphate of lime. M. Berzelius says, that he has detected in it the fluoric acid. Perhaps it is not the same, at different periods of gestation. There is also a fluid between the chorion and amnios, in the second month of pregnancy, but it disappears during the third.

Until the end of the third week, the ovum exhibits no appearance of the germ; the fluid it contains is transparent and partly coagulable as before. At this period, we begin to perceive that the side of the ovum adheres to the uterus, being a slightly opaque gelatinous mass, all the parts of which appear homogenous. Soon, some points become more opaque, and there are two distinct vesicles of nearly equal size, united by a sort of foot stalk, one of these vesicles adheres to the amnios by a small filament. About the same time, there appears in the middle of the last a red point, from which yellowish filaments are seen to pass off; this is the heart and principal blood vessels. At the commencement of the second month, the head is visible, the eyes forming two black points, quite large, in proportion to the volume of the head. Small openings indicate the place of the ears and nostrils; the mouth is at first large, but becomes contracted as the lips become developed, which happens towards the sixtieth day; at this time, the ears, nose and limbs, are likewise perceptible.

By the end of about the fourth month, all the principal organs have become successively developed. At this time, the *embryo* state ceases, and the fœtal state begins, which continues until the end of pregnancy. During this time, all the parts increase, with more or less rapidity, and approach the state they exhibit at birth. We have already spoken sufficiently of the peculiarities of the functions of relations, and we shall now say something respecting those of nutrition.

Before the sixth month, the lungs are very small; the heart is large, but its four cavities are confounded, at least difficult to distinguish; the liver is large, and occupies a great part of the abdomen; the gall bladder is not full of bile, but of a colourless fluid, which is not bitter; at its lower part, the small intestines contain a yellowish matter, in small quantity, called the meconium; the testicles are placed on the sides of the superior lumbar vertebræ, and the ovaria occupy the same position. At the end of the seventh month, the lungs assume a reddish tint, which they had not before; the cavities of the heart become distinct; the liver preserves its large dimensions, but is a little above the umbilicus; the bile appears in the gall bladder; the meconium is more abundant and descends more into the large intestines; the ovaria approach the pelvis, and the testicles the rings. At this period, the fœtus becomes capable of living, independently of the mother; it continues to grow more perfect until the eighth or ninth month, when it is expelled from the uterus. We cannot give here the interesting details of this increase of the organs; they belong to anatomy; but we shall occupy ourselves, for a short time, with the physiological phenomena to which they relate.

Functions of the Ovum and Fœtus.

Soon after the ovum has reached the cavity of the uterus, its rough surface is transformed into sanguineous vessels; life, therefore, exists in the ovum. But we have no idea of its mode of existence; it is probable, that its surface absorbs the fluids with which it is in contact, and that these, having undergone a particular elaboration by the membranes, are afterwards poured into the cavity of the amnios. What, we may inquire, was the germ before its appearance? Did it before exist, or is it formed at this moment? Does the small, slightly opaque mass which composes it, contain the rudiments of all the organs of the fœtus and adult, or are they created at the instant when they first appear? What can be a nutrition so complicated, so important, which is formed without vessels, or nerves, or apparent circulation? How does the heart begin to move, without the appearance of a nervous system? From whence comes the yellow blood which it at first contains? &c. &c.—In the present state of science, it is impossible to give any satisfactory answers to these questions.

We are ignorant of what takes place in the embryo, while the organs are imperfectly formed; there is, however, a sort of circulation. The heart sends the blood into the large vessels, and newly formed placenta; and, it is probable, that the blood is returned to the heart by the veins, &c. But, when the new being has arrived at the fœtal state, and the greater number of the organs have appeared, it is then possible to recognise some of the functions peculiar to this state. Of the different functions of the fœtus, the circulation is best understood. It is more complicated than in the adult, and is entirely different. In the first place, it would be impossible to make the division of the blood vessels into arterial and venous; for the blood of the fœtus has every where the same appearance, it is of a brownish red tint; in other respects, it resembles the blood of the adult; it coagulates, separates into crassamentum and serum, &c. I do not know why some distinguished chemists have asserted, that it does not contain fibrine.

Placenta.—The most singular, and the most important organ of the fœtus, is the placenta; it succeeds those filaments which, during the first month of gestation, cover the ovum. At first, it is very small, but soon acquires considerable magnitude. By its external surface it adheres to the uterus, presenting irregular furrows, which divide it into several *lobes* or *cotyledons*, the number and form of which are not fixed; its fœtal surface is covered by the chorion and amnios, except at it centre, which gives insertion to the *umbilical cord.* Sanguineous vessels, divided and subdivided, form its parenchyma; they belong to the umbilical arteries and vein. The vessels of one lobe do not communicate with those of the neighbouring lobes, but those of the same cotyledon have frequent anastomoses, and nothing is easier than to make injections pass from one to the other.

Umbilical Cord.—This extends from the centre of the placenta to the umbilicus of the infant; its length is often two feet; it is formed by the two umbilical arteries and the umbilical vein, united by a dense cellular tissue. It is covered by the two membranes of the ovum. In the first months of gestation, a vesicle, to which some small vessels, prolongations of the mesenteric artery and vein, are sent, are found in the thickness of the cord, between the chorion and amnios, not far from the umbilicus. This membrane is not analogous to the *allantois*, but more nearly resembles the yellow membrane of birds and reptiles, and the umbilical vesicle of mammiferous animals. It contains a yellowish fluid, which appears to be absorbed by the veins expanded over its walls.*

Having arisen at the placenta, and arrived at the umbilicus, the umbilical vein enters the abdomen, and passes into the lower surface of the liver, there it divides into two large branches, of which one is distributed to the liver with the vena portæ, and the other terminates suddenly in the vena cava, under the name of *ductus venosus.* This vein has two valves, the one at the place of its bifurcation, and the other at its junction with the vena cava. The heart and large vessels of the fœtus, after the seventh month, are very different from what they are after birth. The valve of the vena cava is very much developed, the partition of the auricles is perforated with a large opening, garnished with a valve, called the *foramen ovale.* The pulmonary artery,

* See the Memoir of M. Dutrochet on the envelopes of the egg, inserted among those of the Medical Society of Emulation, vol. viii. and the interesting researches of M. Cuvier on the same subject. (Annales de Museum, 1817.)

after having sent two small branches to the lungs, terminates in the aorta; it is called in this place the *ductus arteriosus.*

Another character peculiar to the circulation of the fœtus, is the existence of the umbilical arteries, which arise from the internal iliacs, run along the sides of the bladder, pass out from the abdomen through the umbilicus, to the placenta, where they are distributed in the manner before described. From this arrangement of the circulating apparatus of the fœtus, it is evident, that the course of the blood must be very different from that of the adult. If we suppose that the blood goes from the placenta, it is evident that it passes through the umbilical vein to the liver; there a part of the blood is directed to the liver, and another to the vena cava, these two routes lead to the heart by the vena cava inferior; having arrived at this organ, it penetrates into the right and left auricle, traversing the foramen ovale at the moment they are dilated. At this moment the blood of the vena cava inferior unavoidably mixes with that of the vena cava superior. Indeed, how could two fluids, of nearly the same nature, remain separate in a cavity, where they arrive at the same time, and which contracts to expel them? I am not ignorant, that Sabatier, in his beautiful Memoir on the Circulation of the Fœtus, has maintained a contrary opinion; but I confess, his reasons have, by no means, altered my opinion in this respect.

The contraction of the auricles succeeds their dilatation, and the blood is forced into the ventricles; these in their turn contract and expel the blood, the left into the aorta, and the right into the pulmonary artery; but this artery terminates in the aorta, with the exception of a very small branch, which goes to the lungs. Under the influence of these two agents of impulsion, the blood passes through all the divisions of the aorta, and returns to the heart by the venæ cavæ; but it is partly carried to the placenta, by the umbilical arteries, and returned by the vein. It is easy to conceive the utility of the foramen ovale and the ductus arteriosus. The left auricle, receiving but little blood from the lungs, could not supply the ventricle, if it did not receive it from the foramen ovale. On the other hand, the lungs not having any functions to perform, if all the blood of the pulmonary artery was sent to them, the action of the right ventricle would be lost; whereas by means of the ductus arteriosus, the force of the two ventricles is employed, to propel the blood in the aorta; without this action of both ventricles, it is probable that the blood could not arrive at the placenta and return again to the heart.

The motions of the heart are very rapid in the fœtus; they generally exceed one hundred and twenty pulsations in a minute; the circulation is, of course, proportionally quick. A question now presents itself, which is extremely difficult, viz. What relation does the circulation of the mother bear to that of the fœtus?—To arrive at any thing like a satisfactory answer, it is in the first place necessary to examine the mode by which the placenta is united with the uterus. Anatomists have varied in opinion on this point. It was for a long time believed, that the uterine arteries anastomosed directly with the branches of the umbilical veins, and that the last divisions of the placenta terminated in the veins of the uterus. But the impossibility of making injections pass from the umbilical vein into the uterine arteries, and *vice versa*, being demonstrated, this idea was abandoned. It is generally admitted now, that there does not exist any anastomosis between the sanguineous vessels of the placenta, and those of the uterus. I have made some researches on this point, and the following are the results.

I at first repeated the attempts to inject the placenta from the uterine vessels, but without success; I even attempted this in living animals without being more fortunate; I have used poisonous substances, the effects of which I was before acquainted with, odorous substances, &c. but I have seen nothing which has induced me to suspect, that there is any direct communication. In bitches, towards the middle of gestation, a great number of small arteries may be distinguished, passing out from the tissue of the uterus, and dividing into numerous ramifications. At this period, it is impossible to separate these two organs without tearing these small arteries, and producing considerable hœmorrhage. But towards the end of gestation, in removing the placenta, however freely, these small vessels separate without the extravasation of blood. When we inject into the veins of a dog, a certain quantity of camphor, the blood becomes of a strong camphorous odour. After having done this on a slut, in the latter period of gestation, I took a fœtus from the uterus, at the end of three or four minutes, its blood had not the odour of camphor. But that of a second fœtus, extracted after a quarter of an hour, had the odour of camphor, very distinctly. The same was found to be the case with the other fœtuses.

Thus, notwithstanding there is no direct anastomosis between the vessels of the uterus and placenta, it cannot be doubted that the blood of the mother, or some of its parts, passes to the fœtus with a certain degree of promptitude. It is probably deposited by the uterine vessels on the surface, or in the tissue of the placenta, and absorbed by the extreme branches of the umbilical vein.

It is much more difficult to determine whether the blood of the fœtus returns to the mother. Among the small vessels which go in animals from the uterus to the placenta, we see nothing which has the appearance of a vein. In women, there are large openings, which communicate with the uterine veins, seen in that part of the uterus, which adheres to the placenta. But we are ignorant whether these venous orifices are destined to absorb the blood of the fœtus, or to allow the blood of the mother to escape to the surface of the placenta; we may admit this last idea to be true, but there is no evidence of it. I have introduced into the vessels of the umbilical cord, active poisons, directing them towards the placenta; but I have never seen the mother experience any effects, and even when she has died of hæmorrhage, the vessels of the fœtus remained full of blood.

As no anastomosis with the vessels of the uterus exists, it is probable that the circulation of the mother has no other influence upon that of the fœtus than pouring blood into the fissures of the placenta. The heart of the fœtus is the principal moving power of its blood. It is, however, asserted, that well formed fœtuses have been born without any heart. But can these observations be depended on? There have been well authenticated cases where the placenta was entirely separated from the dead fœtus, while it has continued to develope itself. M. Ribes, recently observed a case where the umbilical cord was ruptured and perfectly cicatrised; how was the circulation carried on in this organ? We must conclude, therefore, that the relations between the circulation of the mother and that of the fœtus, require new experiments.

Some authors have asserted that the placenta is to the fœtus, what the lungs are to the adult; others have endeavoured to explain the large volume of the liver, by attributing to it the same use. These assertions are entirely unsupported by proof. The functions of the capsulæ renales, thymus and thyroid glands, the dimensions of which in the fœtus are considerable, are also at present involved in impenetrable obscurity. This subject has often exercised the imaginations of physiologists, but without any real benefit to science.

Notwithstanding the imposing authority of Boerhaave, it is impossible to admit, that the fœtus continually swallows the water of the amnios, digests it, and is nourished by it. Its stomach, it is true, contains a viscid matter in considerable quantity; but it resembles, in no respect, the *liquor amnii;* it is very acid and gelatinous; towards the *pylorus* it is greyish and opaque. It appears, that it is formed in the stomach, that it passes into the small intestines, where, after having undergone the action of the bile, and perhaps the pancreatic juice, it furnishes a particular chyle. The remainder descends towards the large intestines, where it forms the meconium, which is evidently the result of digestion carried on during gestation. Whence, it may be inquired, arises this digested matter? It appears probable, that, it is secreted by the stomach itself, or that it descends from the œsophagus; there is nothing, however, opposed to the idea, that in certain cases, the fœtus may swallow some mouthfuls of the liquor amnii; the fact that hairs, similar to those of the skin, are sometimes found in the meconium seems to prove this. It is important to remark, that the meconium is a substance that has little azote.

Nothing is at present known, respecting the use of this digestion in the fœtus; it is not probable, that it is essential to its development, inasmuch as it cannot exist in those instances where there is no stomach; nor any thing which answers to it. Some persons assert, that they have seen the chyle in the thoracic duct of the fœtus. I have never seen any thing of the kind; in living animals, this canal and the lymphatics contain a fluid which appears to be analogous to the lymph, and which coagulates spontaneously like it. I have made some attempts to satisfy myself, by direct experiments, whether venous absorption took place in the fœtus in utero. I have injected into the pleura, peritoneum, and the cellular tissue, active poisonous substances, but I could not obtain any satisfactory result, as the nervous system of the fœtus, when it has not respired, appears to be insensible to the action of poisons. It appears certain, that exhalations take place in the fœtus, as all its surfaces are lubricated nearly as they are afterwards; the fat is abundant, and the humours of the eye exist. It is also probable, that cutaneous transpiration takes place, and is continually mixed with the liquor amnii. With respect to this last fluid, it is difficult to say whence it is derived; no sanguineous vessels appear on the amnios, it is nevertheless probable, that this membrane is its secretory organ.

The cutaneous and mucous follicles are developed, and appear to have a powerful action, especially after the seventh month; the skin is then covered by a thick coat of fatty matter, secreted by the follicles. Many authors have considered this as a deposition from the liquor amnii; the mucus is also very abundant in the two last months of gestation. All the glands, which assist in digestion, are of considerable size, and appear to have a certain degree of activity, we know but little of the others. We are ignorant, for example, whether the kidneys form urine, and whether this fluid is thrown out by the urethra into the cavity of the amnios. The testicles and mammæ appear to form a fluid, which does not resemble either semen or milk, which is found in the vesiculæ seminales, and lactiferous ducts.

What then can we say of the nutrition of the fœtus? Physiological works contain only vague conjectures on this point. It appears certain, that the placenta receives from the mother, the materials necessary to the development of the organs; but we are ignorant of the nature of those materials, and how they are obtained. Respiration not having taken place before birth, its heat cannot depend upon this. Experience has shown, that it does not rise above 94° or 95° of Faren.; it is said to be more elevated when the fœtus in utero is dead. If this be true, the fœtus must have a means of cooling itself, which does not exist after birth. This is all we know of the nutritive functions of the fœtus; what relates to the functions of relation, has been already explained.

As the mother transmits to the fœtus the materials necessary to its nutrition, it will be necessarily modified by the nature and quantity of the materials transmitted. If the quality be good, and the quantity sufficient, the growth will be natural, but if the proportion be small, or if the quantity be not proper, the fœtus will be badly nourished, and will either cease to be developed, or even perish. Now the moral condition of the mother must modify the nature and properties of these elements, which pass to the placenta; it is true, therefore, that her imagination has an influence upon the fœtus. It is thus that sudden terror, violent chagrin, or immoderate joy, may cause the death of the fœtus, or retard its growth. Physical causes, such as blows, falls, the action of certain medicinal agents, and the bad quality of the aliments, may have the same result, because they diminish or prevent the transmission of nutritive materials to the fœtus. If the mother be affected by a contagious disease, the fœtus will have symptoms of it; thus the life of the fœtus is in an evident state of dependence upon that of the mother.

Independently of the lesions which arise from this source, the fœtus is frequently attacked with spontaneous diseases; such as dropsies, ulcers, fractures, gangrenes, cutaneous eruptions, the separation of one or more of the limbs, and many other internal diseases, both local and general. They often die of these diseases before birth, and if they are permitted to live until after birth, they are no longer capable of supporting life. The membranes of the ovum, placenta, and liquor amnii, are also sometimes found in a morbid state.

Of Monstrosities.—In consequence of some unknown cause, the different parts of the fœtus sometimes develope themselves, in a preternatural manner; so that one or more of the natural emunctories of the body do not exist, or are closed by membranes. Sometimes the lungs, stomach, bladder, kidneys, liver, and even brain, are entirely wanting, or are arranged in an unusual manner. In general, according to the remark of M. Beclard, when a nerve is wanting, the parts to which it should be distributed do not exist. There are other malformations or monstrosities, which depend on unknown causes, and seem to arise from a confusion of two germs, from which result children with two heads and one trunk, or two trunks and one head, or one trunk and four arms, or four legs well formed. There have been often found, fœtuses not developed, in the bellies of individuals in advanced age. There is no reason for believing that the imagination of the mother can have any influence in the formation of these monsters; besides, productions of this kind are daily observed in the offsprings of other animals, and even in plants.

It is not very unusual for the uterus to contain two, instead of one fœtus. In France, this occurs as often as one in eighty, it appears to be more frequent in England. Three fœtuses in one gestation is much more rare; in thirty-six thousand labours in the "Hospice de la Maternité," in Paris, only four cases of this kind happened. There have been some well authenticated instances, where women have had four fœtuses in one gestation; but, beyond this, the instances related by authors appear to be fabulous. In cases of plurality of children, the volume and weight of the children are in proportion to the number; twins are smaller than common children, &c., but whatever may be their size, they are each surrounded with a separate amnois and chorion, and have a distinct placenta. Their functions are separate, so that one may die while the others continue to become developed. There is nothing to countenance the belief, that in case of plurality of children, fecundation took place at two or three different times, and that there really exist instances of superfœtation. The histories of this, which have been related, are far from resting on the degree of evidence, which is necessary in a science of facts.

Of Parturition.

At the end of the seventh month of gestation, the fœtus is in a condition to respire and exercise its digestive functions; it is then capable of an independent existence. It is rare, however, that parturition takes place at this time; it generally occurs at the end of nine calendar months. There have been examples cited, of the birth of children at the end of ten full months of gestation; but these cases are very doubtful, as it is so extremely difficult to determine the precise period of conception. According to the French Code, however, it is an established principle, that parturition may take place at the end of two hundred and ninety-nine days of gestation.

Nothing is more curious, than the mechanism by which the fœtus is expelled; every thing seems to have been foreseen and provided for, with an admirable precision, so as to favour its passage through the pelvis and organs of generation. The physical causes by which this is effected are, the contraction of the uterus and abdominal muscles; through their agency, the membranes are ruptured, the water of the amnios discharged, the head of the fœtus forced into the pelvis, and passed through the *vulva*, the folds of which are effaced. These different phenomena take place in a regular succession, and are accompanied by pains, more or less severe, by swelling and relaxation of the soft parts about the pelvis, and the external organs of generation, and an abundant mucous secretion in the cavity of the vagina. All these circumstances, each in its particular way, favour the passage of the fœtus. To facilitate the study of this complicated operation, it is necessary to divide it into several stages, or periods.

First stage of Parturition.—It consists of premonitory signs. Two or three days before parturition, an unusual discharge of mucus from the vagina, is observed to take place; the genital organs are swollen, and become relaxed, and it is the same of the ligaments which unite the bones of the pelvis. The neck of the uterus becomes flattened, its opening enlarged, and its edges thinner; and slight pains, which are known in France under the name of *mouches*, or flee bites, are noticed in the loins and belly.

Second stage.—Pains of a different kind are soon developed; they appear to begin in the loins, are propagated either toward the fundus, or neck of the uterus, and are renewed after considerable intervals, e. g. a quarter or half an hour. Each is accompanied by an evident contraction of the body of the uterus, a manifest tension of its neck, and a dilatation of its mouth, or *os tincæ*. If the finger be now introduced into the vagina, we can distinguish the envelops of the fœtus, projecting from the os tincæ. The contractions gradually become stronger, and the pains more severe, by which the membranes are at last ruptured, and the water discharged; when the action of the uterus is directly applied to the fœtus.

Third stage.—The pains and contractions of the uterus, now considerably increase, and are instinctively accompanied with contractions of the abdominal muscles. Women, perceiving their effect, are induced often, to make all the muscular efforts that they are capable of. The pulse is also frequently increased, the countenance animated, and the whole body in extreme agitation, the sweat pouring from the surface in great abundance. The head being engaged in the pelvis, the occiput at first placed above the left acetabulum is carried inwards and downwards, and is passed beneath and behind the arch of the pubis.

Fourth stage.—After some instants of repose, the expulsive efforts recommence; the head presents at the vulva, and endeavours to pass through, which is at last effected by a strong effort. When once the head is disengaged, the rest of the body soon follows. The umbilical cord is now tied, and divided, at a short distance from the navel.

Fifth stage.—If the accoucheur does not immediately proceed to extract the placenta, in a short time, slight pains are observed again; the uterus contracts feebly, but with sufficient force to expel the placenta and membranes; this has received the name of *deliverance.* During twelve or fifteen days, which succeed parturition, the uterus resumes, gradually, its original size and form, the woman perspires freely, and the mammæ become distended with milk. A discharge, at first bloody and afterwards whitish, called the *lochia*, takes place from the vagina, which indicates that the organs are returning to their natural state.

As soon as it is separated from its mother, and sometimes before, the chest of the infant dilates, and the lungs are distended with air; and this motion continues to be repeated for the remainder of life. The lungs, being distended by air, permit the blood to pass through the pulmonary artery, so that the ductus arteriosus and foramen ovale, receiving less blood, contract gradually and at last become obliterated. The same thing takes place in the umbilical vein and arteries, which are transformed into fibrous ligaments. The infant, at birth, is from eighteen to twenty inches in length, and weighs five or six pounds. In general, the number of male is greater than that of female children. The number of children that may be born of one mother, cannot exceed the number of vesicles contained in the ovaria, that is about forty.

Of Lactation.

The painful act, that we have now described, does not terminate the duties of the mother; the infant now requires care of a different kind; it must be protected against the weather; great attention is required for its preservation, and for its moral and physical education; lastly, nature has confided to her the power of furnishing its first aliment, and the only one suitable to the delicacy of its organs. This aliment is milk, it is secreted by the mammæ; the number, form, and situation of which are among the distinctive characters of the human species. Their parenchyma is entirely different from that of the other secretory organs. Each mamma has twelve or fifteen secretory ducts, which open at the top and sides of the mammary process, or nipple. The arteries which are distributed to the mammæ, are small, but very numerous; they abound with lymphatic vessels and nerves, and are endued with a vivid sensibility. The mammary process, in particular, is very sensible and is susceptible of a state analogous to erection.

Until the period of fecundation, the mammæ remain inactive, not exercising any apparent secretion. But in the early periods of pregnancy, the woman observes peculiar pricking and darting pains, and the organs become swelled. After a certain period, especially as the end of gestation approaches, a serous fluid, sometimes in considerable quantity, is discharged from the nipple. The secretion often preserves the same characters for two or three days after delivery; but the milk, properly so called, does not appear until the end of that time.

The milk is one of the most azotic of the glandular fluids; its smell, colour, and taste, are well known. According to M. Berzelius, it is composed of cream and milk, properly so called; the last contains, 928.75 parts of water; 28.00 of caseous matter, with sugar; 35.00 of sugar of milk; 1.70 of muriate of potash; 0.25 of phosphate; 6.00 of the lactic acid; acetate of potash, and lactate of iron, 0.30. The cream contains butter 4.5, cheese 3.5, whey 92.0, or we find 4.4 of the sugar of milk and salt.

It has been long observed, that the quantity and nature of the milk changes with the quantity and nature of the aliments; this has given rise to the singular opinion, that the lymphatics were the vessels destined to carry to the mammæ, the materials of their secretion. But it is the same with the milk, as it is with the urine, the properties of which vary with the solid or fluid substances introduced into the stomach. For example, the milk is more abundant, thicker and less acid, if the woman is nourished with animal substances; it is less abundant, thinner, and more acid, if the diet be vegetable. The milk also assumes particular qualities, if the woman has taken medicinal substances, it becomes purgative, for example, when rhubarb, jalap, &c. have been used. The secretion of milk is prolonged until the organs of mastication shall become sufficiently developed to prepare the aliment for digestion; it does not cease until the course of the second year; although the secretion of milk seems peculiar to parturient females, it has sometimes been observed in young virgins, and even men.*

OF SLEEP.

In terminating the history of the functions of relation, we remarked, that these functions were periodically suspended; we also added that during this suspension, the nutritive and generative functions were modified; and we are now about to examine these phenomena. After having been awake for sixteen or eighteen hours, we experience a general sensation of fatigue and weakness. Our motions become more difficult, our senses lose their activity, and the understanding itself becomes disturbed; perceiving sensations imperfectly, and commanding the contraction of the muscles with difficulty. From these signs we perceive the necessity of giving ourselves up to sleep; we choose a position that requires no effort to preserve it, we seek darkness and silence, and then abandon ourselves to repose.

* I have not thought proper to introduce into this work, a particular description of the different ages, sexes, temperaments, zoological character of man, &c. These considerations properly belong to hygiene and natural history. See the article Hygiene, in the Encyclopedie Methodique, and the new work of M. Cuvier, on the Animal Kingdom.

In sleep, we lose, successively, the use of our senses; vision is prevented by the eye-lids being closed; smell ceases after taste, hearing after smell, and touch after hearing; the muscles of the extremities become relaxed, and cease to act before those of the head and spine. In proportion as these phenomena take place, respiration becomes slower and more profound; the circulation is retarded; more blood is carried to the head, the animal heat is diminished, and the secretions less abundant. However, when man is plunged into this state, he does not immediately lose a sense of his existence; he is still conscious of many of the changes which take place around him; a state which is not without its charms; ideas, more or less incoherent, succeed. At last he entirely ceases to be conscious of his existence, he is then asleep. During sleep, the circulation, respiration, and the different secretions, remain slower, of consequence digestion is effected with less promptitude. I do not know on what plausible ground many authors have asserted that absorption alone acquires new energy. As the nutritive functions continue in sleep, it is evident, that the brain only ceases to act as the organ of intelligence and muscular contraction; but that it continues to influence the muscles of respiration, the heart, the arteries, the secretions, and nutrition.

Profound sleep exists, when it is necessary to employ strong excitants to remove it; it is *light*, when it ceases easily. Complete sleep is such as I have described; i.e. it is the result of the suspension of the action of the organs of relation, and of the diminished action of the nutritive functions. But it is not rare that many of the organs of relation preserve their activity during sleep; as when we sleep standing. It may happen also, that one or more of the senses remain awake, and transmit to the brain impressions which they receive; it is still more common for the brain to take cognizance of the different internal sensations which are developed during sleep, such as wants, desires, grief, &c. The understanding may exert itself during sleep, either in an irregular and incoherent manner, or regularly and logically, as we meet with in some individuals.

The direction that the ideas take in sleep, or the nature of the dreams, depends very much on the state of the organs. If the stomach be overcharged with undigested aliment, or if the respiration be difficult, from the position or other causes, the dreams will be disagreeable and fatiguing. A sensation of hunger will cause us to dream of agreeable repasts, &c. The habitual occupation of the mind will not have less influence upon the train of our ideas; the ambitious dream of success or disgrace, the poet makes verses, and the lover sees his mistress. It is because the judgment sometimes exerts itself in its full strength during our dreams, relatively to future events, that this has been imputed to divination by the superstitious.

There is nothing more curious in the study of sleep than the state of *somnambulists*. These individuals first sleep profoundly, they then rise up suddenly, dress themselves, understand, see, speak, use their hands with address, give themselves up to different exercises, write, compose, and return to bed, and, on awakening the next day, preserve no recollection of any thing that has happened. What difference is there, then, between a somnambulist of this kind, and a man awake? There is only one evident difference; the last is conscious of his existence, and the other is without it. We shall not, with some authors, seek after the proximate cause of sleep, and find it in a weakening of certain parts of the cerebellum, the afflux of the blood to the brain, &c. Sleep, being an immediate effect of the laws of organization, cannot depend on any physical cause of this kind. Its regular return is one of those circumstances which contribute most to the preservation of the health; when it is long prevented, it is often followed by serious inconveniences; and in no case can be carried beyond certain limits.

The duration of sleep is variable; in general it is from six to eight hours; fatigue of the muscular system, great agitation of mind, numerous vivid sensations, indolent habits, the immoderate use of wine and substantial food have a tendency to prolong it. In infancy and youth, the functions of relation being very active, more rest is required. Mature age, more avaricious of time and surrounded by cares, requires much less. In old age, the two opposite extremes generally exist, either almost continual somnolency, or but very little disposition to sleep. By a quiet uninterrupted sleep, restrained within due limits, the vital powers of the body are restored, and the organs resume their aptitude to act with facility. But, if disagreeable dreams or painful impressions disturb our sleep; or if they are merely prolonged beyond a suitable limit; so far from restoring, it diminishes the forces, fatigues the organs, and becomes often a cause of serious diseases, such as idiotism and madness.

OF DEATH.

The individual existence of all organised bodies is temporary; no animal escapes the hard necessity of dying; nor is man exempt from this. The particular history of each function shows that in the first periods of old age, and often before, the organs become deteriorated; that many completely cease to act; that others are absorbed and disappear; and, lastly, that in decrepitude, life is reduced to a few miserable remnants of the vital, and some of the nutritive functions in an imperfect state. In this condition the most trifling external cause, the slightest blow or fall, is sufficient to arrest one of the functions indispensable to life, when death immediately follows, as the last degree in the destruction of the organs and functions. But a small number of persons die solely through the effects of age; it scarcely happens to one in a million; the remainder die at every period of life, by accidents and diseases; and this great destruction of human life, by causes apparently accidental, appears to be provided for by nature, with as much care, as she takes to secure the reproduction of the species.

APPENDIX.

No. I.

The author of the Summary, &c. has not entered very fully into a consideration of the physiology of the brain, but has deferred to some future opportunity, his observations on this point. There is one department of it which has excited considerable interest among scientific men, that he has scarcely touched; I allude to Dr. Gall's System of Craniology. To have entered fully into the consideration of this subject, involved, as it is, with much that is visionary and fanciful, would not have comported with the spirit of this book. But, as there is much in this system which is curious and worthy of attention, and as I do not know of any source, generally accessible in this country, where a knowledge of it may be acquired, I have thought that this work, which is designed for the American medical student, would be rendered more complete by appending to it a brief abstract of these doctrines, and some of the facts and reasonings on which they are founded.

Although, from the very constitution of man, one of the first reflections he must make, when contemplating himself, is the remarkable relation which exists between his brain and the operations of his intellect; yet the attempt to trace a connexion between the volume and form of this organ, and the character of the individual, and to reduce it to a science, is of quite modern date. The first elaborate essay on this subject, was made by Daubenton, in a memoir on the situation of the foramen magnum of the occipital bone, in man and animals, read before the French academy, in 1763. About thirty years afterwards, the subject was taken up by Camper, who endeavoured to lay down rules by which we might judge of the nation and intellect of the individual, from the mechanical form of the cranium, measured in certain directions. For this purpose, he collected together a great number of skulls from different countries, and, having compared them, at length proposed as a rule for solving this problem, what he called the *facial angle.* This is formed by the two following lines; viz. one passing from the anterior part of the alveolar margin of the upper jaw, to the most prominent part of the forehead, above the nose, and the other from the first mentioned point, through the meatus auditorius externus. It will be seen from this, that as the forehead becomes full and prominent, that the angle formed by these lines increases, and, on the contrary, that when the forehead is retreating and the bones of the face prominent, this angle will diminish. As the facial angle is increased, the sublimity and beauty of the outline of the human head increases, until it reaches 100°, but if the angle be increased beyond this, it produces deformity; on the contrary, as the angle diminishes, the outline approaches that of the brute. It has been found, by extensive observation, that the facial angle in man actually ranges from 70° to 80°. It is about seventy in the Carib and Negro, and about eighty in the European. It would seem, from experience, that the facial angle of Camper indicates, with considerable fidelity, the capacity of the cranium, and the intellectual character of the individual. But it is not without objections; one of the most obvious is, that, as it refers to the dimensions of the cranium in one direction only, it must shew its capacity but imperfectly.

The system of Doctors Gall and Spurzeim, goes much farther; it professes not only to point out, generally, the intellectual character of the individual, but to determine, with precision, the disposition and propensities of the individual, from the form of the cranium and certain prominences about it. Instead of dissecting the brain, like other anatomists, with a sharp instrument, and shewing its structure by successive sections, beginning at the top of the cerebrum and proceeding downwards, they employ a blunt instrument, beginning at the base and proceeding upwards, by which they are enabled to follow, with more accuracy, the natural arrangement and texture of the organ. From this mode of dissection, they are led to infer, that the brain is not homogeneous, as some have supposed, but demonstratively fibrous. Among the peculiar opinions arising from this mode of dissections, is the doctrine, that the encephalon is not a mere pulpy mass, but a membrane; in this way they account for the intelligence frequently observed by the hydrocephalic patients, even when there is an apparent disorganization of the brain.

"It may be proved by anatomy," say they, "that the fibres of the brain are directed perpendicularly upwards, from the cerebral cavities; and that every convolution consists of two layers applied vertically, one to another, and separable from each other. If, therefore, a great quantity of water be accumulated in the cerebral cavities, and act against the convolutions placed around these cavities, it gradually separates the two layers, whose natural position is vertical, till at last they become horizontal. In this manner, in large hydrocephalic skulls, the convolutions are entirely unfolded, and present a smooth surface and membranous expansion.

"Thus the cerebrum is made up of thin convolutions of medullary and cortical substance, surrounding the two lateral ventricles, which are unfolded when the cavities of those two ventricles are enlarged, and in this unfolded state, the functions of this part of the organ can be carried on."

With these and some other peculiar views, as to the anatomical structure of the brain, they endeavour to prove, first, that it is "the seat of the soul," the "organ of the feelings and intellectual faculties," though this is denied by some, and even by the high and modern authority of Bichat. Taking it then as an established point, that the brain is the seat of thought, they endeavour to show that it is not a single organ, but is composed of as many single organs, as there are particular and independent manifestations of mind. They contend, that when these different parts of the brain, or, as they call them, organs, become developed in a remarkable degree, that this is manifested not only in the intellectual character of the individual, but likewise in the increased prominence of that particular part of the cranium. By very careful and extensive observation, they conceive it practicable to determine with considerable precision, the relative position of these different organs, and that in fact they have already ascertained this. They have accordingly divided the cranium into thirty-three parts, and have given a name to each, indicative of the peculiar quality of mind manifested in those individuals, in whom this particular part or organ has been observed to be remarkably developed.

Our limits will not permit our giving more than this very brief and imperfect outline of the system of craniology, of Drs. Gall and Spurzeim. Indeed, after more deliberately perusing the cautions of the author of the "Summary," on the dangerous tendendency of indulging a spirit of speculation in physiological inquiries, I have almost regretted having at all entered upon the subject.

It cannot be denied, that there is something extravagant and incredible in the first aspect of this system, yet it is equally true, that these gentlemen have investigated the subject with singular industry, and have collected together a great number of curious and remarkable facts, to illustrate and prove the truth of their doctrines; and it is undoubtedly true, that they have among their most sanguine followers, many persons eminently distinguished for their intelligence. It will also be confessed, that their researches have given rise to some original views of the anatomical structure of the brain, which explain, plausibly enough, some surprising circumstances in the pathology of this organ. Lastly, I will observe, that the doctrines are elaborately illustrated from morbid phenomena, dissections of the brains of ideots, known experiments on living animals, natural history, and comparative anatomy.* [*Trans.*

No. III.

The classification of the functions by Magendie, is essentially the same as that of Bichat. By the first they are divided into those of relation, nutrition, and generation; by the last into the functions of animal and organic life, and generation. In fact, the two first differ chiefly in name. There are certain remark-

* Vide Physiognomical System of Drs. Gall and Spurzeim.

able distinctive characters, possessed by the two first classes of functions, or modes of life, which are much insisted upon by Bichat, but are scarcely noticed by Magendie. They appear to me to be curious, and well worthy of a place in an elementary treatise on physiology. After having enumerated these two classes of organs, I will state, very concisely, some of these differences.

The following is the foundation of his distinction of *animal* and *organic life.* All the functions of organized bodies may be referred to two great classes, those relating to the individual and those to the species. He called those functions which connect us with external bodies *animal life;* thus indicating, that this order belongs to animals alone, and that it is the addition of these functions, that particularly distinguishes them from vegetables. He called, on the contrary, those which serve for the constant composition and decomposition of our bodies, functions of *organic life;* because this order of functions is common to all organized beings, animals and vegetables. This last order serves as a line of distinction between organic and inorganic bodies.

The organs of *animal life* are, 1st, those of locomotion, and 2nd, those of the voice; the two modes by which animals communicate voluntarily with surrounding objects. 3rd. The external senses, which receive external impressions. 4th. Internal sensations, which perceive, reflect, and combine them, and, in consequence, form volitions. 5th. The organs for the transmission of sensation and motion, which establish the communication between the external senses which receive, and the internal, which perceive impressions; between those which form volitions, and the vocal and locomotive organs which execute them.

The organs of *organic life* are, 1st, those of digestion. 2nd. Those of respiration, which receive from the air certain principles necessary to the blood, to enable it to nourish the organs, and reject others. 3rd. Those of the circulation, which carry to all the organs nutritive substances. 4th. Those of absorption. 5th. Those of secretion.*

The most remarkable circumstances which distinguish the organs of animal from those of organic life are, the symmetry of

* Vide Anatomie Descriptive, par Bichat.

the one, and the irregularity of the other. The organs of animal life, are very equally divided into pairs, between which the most perfect symmetry and resemblance prevail. The body is, in this respect, divided into two parts, with mathematical precision, the line of demarkation being indicated at various points; viz. the fissure beneath the nose, the chin, the *raphe* of the perineum, &c. The brain is divided in a similar manner, and the nerves passing out from it to the agents of locomotion and voice, the organs of animal life, are also arranged in symmetrical pairs, with the most perfect regularity. But the reverse of all this is found to exist in the organs of organic life. The heart and arteries, the organs of respiration, the digestive viscera, absorbents, &c. are all irregularly disposed; and, unlike the organs of animal life, this irregularity in the arrangement of one side, never affects the functions of the other. The sources from which the nerves distributed to these two classes of organs are derived, is a circumstance worthy of notice. "It is well known, that the animal functions, sensation, locomotion, and voice, are under the direction of the cerebral nerves; on the contrary, that most of the organs of organic life receive their nerves, and, with them, their principle of action, from the ganglions." (Great sympathetic.)*

The necessary consequence of the symmetrical arrangement of the organs of animal life is, that, as they are alike in structure, they must resemble each other in their mode of action, and if one be stronger than the other, the function will be imperfect. If one eye be stronger than the other, vision is imperfect, &c. &c. But the reverse is the case in the organs of organic life; if one kidney be stronger than the other, or one lung more vigorous than its fellow, no derangement is produced in the exercise of the respective functions of these organs. Hence it often happens, that there are great irregularities in structure, and defects in the organs of organic life, without any disturbance in the functions.

There is another remarkable difference in these two functions, to which we would more particularly call the attention of the reader. It is the periodical intermissions necessary in the ani-

* See Bichat's Researches on Life and Death.

mal organs, and their uninterrupted continuance in those of organic life. The first class is capable of acting for a certain length of time, after which their power becomes exhausted, and they must then remain, for a considerable period, in a state of repose. All the senses, after having been long active, become unfit to receive new impressions, until they are refreshed by rest; the same remark applies to the imagination, perception, and other faculties of the mind. All the muscles of voluntary motion require periods of relaxation and repose; hence the necessary intermissions of locomotion and voice. The same remark applies to all the functions of relation. But on the other hand, the organs of organic life continue their unwearied action, from their first development, until death takes place. There are moments, when their powers languish from disease, but they never entirely cease but with life. The heart and arteries continue to pulsate, the lungs to play, the abdominal viscera to secrete, and the lymphatics to absorb, until death interrupts their functions. [*Trans.*

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